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Radio Progress During 1938
Lateral Disk Recording
Noise-Reduction Antenna
Oscillograph Design
Constant-Frequency Oscillators
Strength of Atmospherics
U-H-F Measuring Assembly
Internal Impedance of Amplifiers
Electronic Motion in Tubes
Ionosphere Characteristics

Institute of Radio Engineers

FORTHCOMING MEETINGS AND INSTITUTE SECTIONS

JOINT MEETING WITH AMERICAN SECTION OF THE INTERNATIONAL SCIENTIFIC RADIO UNION

Washington, D. C., April 28 and 29, 1939

NEW YORK MEETING—Engineering Societies Building—APRIL 5
33 West 39th Street, New York, New York

ATLANTA	Chairman, Ben Akerman Secretary, J. G. Preston, 230 Ansley Street, Decatur, Georgia	
BOSTON	Chairman, H. W. Lamson Secretary, E. B. Dallin, 64 Oakland Avenue, Arlington, Massachusetts	
BUFFALO-NIAGARA	Chairman, H. C. Little Secretary, E. C. Waud, 235 Huntington Avenue, Buffalo, New York	
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THE INSTITUTE

The Institute of Radio Engineers serves those interested in radio and allied electrical-communication fields through the presentation and publication of technical material. In 1913 the first issue of the Proceedings appeared; it has been published uninterruptedly since then. Over 1500 technical papers have been included in its pages and portray a currently written history of developments in both theory and practice.

STANDARDS

In addition to the publication of submitted papers, many thousands of man-hours have been devoted to the preparation of standards useful to engineers. These comprise the general fields of terminology, graphical and literal symbols, and methods of testing and rating apparatus. Members receive a copy of each report. A list of the current issues of these reports follows:

Standards on Electroacoustics, 1938
Standards on Electronics, 1938
Standards on Radio Receivers, 1938
Standards on Radio Transmitters and Antennas, 1938.

MEETINGS

Meetings at which technical papers are presented are held in the twenty-one cities in the United States and Canada listed on the inside front cover of this issue. A number of special meetings are held annually and include one in Washington, D. C., in co-operation with the American Section of the International Scientific Radio Union (U.R.S.I.) in April, which is devoted to the general problems of wave propagation and measurement technique, the Rochester Fall Meeting in co-operation with the Radio Manufacturers Association in November, which is devoted chiefly to the problems of broadcast-receiver design, and the Annual Convention, the location and date of which is not fixed.

MEMBERSHIP

Membership has grown from a few dozen in 1912 to more than five thousand. Practically every country in the world in which radio engineers may be found is represented in our membership roster. Approximately a quarter of the membership is located outside of the United States. There are several grades of membership, depending on the qualifications of the applicant. Dues range between $3.00 per year for Students and $10.00 per year for Members. Proceedings are sent to each member without further payment.

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The contents of each paper published in the Proceedings are the responsibility of the author and are not binding on the Institute or its members. Material appearing in the Proceedings may be reprinted or abstracted in other publications on the express condition that specific reference shall be made to its original appearance in the Proceedings. Illustrations of any variety may not be reproduced, however, without specific permission from the Institute.

Papers submitted to the Institute for publication shall be regarded as no longer confidential. They will be examined by the Papers Committee and Board of Editors to determine their suitability for publication. Suggestions on the mechanical form in which manuscripts should be prepared may be obtained from the Secretary.

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330 West 42nd Street
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Radio Progress During 1938

PART I—ELECTROACOUSTICS*

THIS review of progress in radio during 1938 is divided into six parts covering the major fields of Electroacoustics, Electronics, Radio Receivers, Television and Facsimile, Transmitters and Antennas, and Wave Propagation. Part I treats the following main divisions of Electroacoustics: theory, loud speakers, microphones, telephone instruments, electromechanical instruments, acoustics of broadcast studios, measurement apparatus and techniques, and electronic musical instruments.

THEORY

A number of contributions to fundamental theory were made which will influence future developments in electroacoustics. Refinements in apparatus largely followed the trends of the immediate past.

The principal theoretical work dealt with modification of the sound field by various rigid bodies. Acoustic time-delay circuits, transverse acoustic waves in conduits, and electroacoustical and electromechanical analogies also received attention.

Additional data were compiled on diffraction caused by square and circular baffles.[1] Diffraction effects of cylinders, cubes, and spheres[2] received further attention.

The exact solution of the diffraction problem in elliptic cylindrical co-ordinates[3] was computed by the use of newly compiled tables of Mathieu functions. Curves were obtained for the distribution in angle and total intensity scattered for the diffraction by a slit or the scattering by a thin ribbon of waves whose length is of the same order of magnitude as the slit or ribbon width.

Acoustic attenuators[4] analogous to the common T and π electrical types were constructed as a result of the development of relatively pure acoustic resistance elements. These have simplified the construction of practical acoustic time-delay[5] circuits.

Transverse acoustic waves guided by rigid cylindrical tubes,[6] which are analogous to electromagnetic waves guided by dielectrics, were investigated. Measured values of wavelength, threshold frequency, and pressure distribution for some of the possible harmonic-wave types are found to be in excellent agreement with theoretical values. The theory made possible the construction of sharp-cutoff high-pass acoustic filters.

LOUD SPEAKERS

No fundamentally new types of loud speakers were developed. The moving-coil direct-radiator type continues its domination of radio applications. Improvements were made which extend the frequency range, diminish the nonlinear and transient distortion, increase the efficiency and power-handling capacity, and reduce the cost.

Extensions of the response-frequency range of direct-radiator moving-coil loud speakers were reported. One design employed a formed aluminum-alloy diaphragm in which damping and a reduction in edge stiffness were obtained by using a viscous plastic material to replace the metal removed from sections distributed around the edge of the diaphragm. Further consideration was given to radiating structures consisting of two or more cones actuated by one or more moving coils.[7] One type employing a multiple cone with a single moving coil was introduced in radio receivers.

The response-frequency, nonlinear distortion, and transient distortion of a loud speaker may be controlled over moderate limits by the use of feedback from its electrical terminals. Suitable networks permit the realization of desirable source impedance characteristics.[8] Further information on the use of negative feedback of this kind was obtained and progress in the problem of feeding back from the mechanical and acoustical circuits reported.[9,10]

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* Decimal classification: 621.385.97.

[1] G. G. Muller, R. Black, and T. E. Davis, "Diffraction produced by cylindrical and cubical obstacles and by circular and square plates," *Jour. Acous. Soc. Amer.*, vol. 10, pp. 6–13; July, (1938).

[2] H. Stenzel, "Ueber die von einer starren Kugel hervorgerufene Stoerung Schallfeldes," *Elek. Nach. Tech.*, vol. 15, pp. 71–78; March, (1938).

[3] Phillip M. Morse and P. J. Rubenstein, "The diffraction of sound by ribbons and by slits," *Phys. Rev.*, vol. 54, pp. 895–898; December 1, (1938).

[4] P. B. Flanders, "Acoustic attenuators," *Bell Lab. Rec.*, vol. 16, pp. 403–407; August, (1938).

[5] A. C. Norwine, "Acoustical delay circuits for laboratory use," *Bell Lab. Rec.*, vol. 16, pp. 400–402; August, (1938).

[6] H. E. Hartig and C. E. Swanson, "Transverse acoustic waves in rigid tubes," *Phys. Rev.*, vol. 54, pp. 618–626; October 15, (1938).

[7] H. F. Olson, "Multiple coil, multiple cone loud speakers," Presented, Acoustical Society of America Meeting, November, 1938.

[8] L. D. Farren, "Some properties of negative feedback amplifiers," *Wireless Eng.*, vol. 15, pp. 23–35; January, (1938).

[9] H. S. Knowles, "Loud-speaker considerations in feedback amplifiers," Presented, I.R.E. Pacific Coast Meeting, Portland, Oregon, August 11, 1938. Summary, PROC. I.R.E., vol. 26, p. 794; July, (1938).

[10] Y. Otuka, "Negative feedback loud speakers," *Electrotech. Jour.* (Tokyo), vol. 2, p. 120; May, (1938).

Further progress was made in realizing the high efficiencies possible in horn-type loud speakers.[11,13] Desirable impedance-frequency characteristics may be obtained by employing a horn consisting of manifold exponential sections.[11,12] The efficiency of a unit having a horn with three rates of flare was shown to approach the ultimate efficiency within a few per cent.

Improved efficiency and power-handling capacity of voice-coil-temperature-limited loud speakers were obtained experimentally by immersing the voice coil in hydrogen and helium.[14] Results are comparable to those obtained in power-plant machinery.

Compactness and reduced cost were obtained in an experimental loud speaker by employing two entirely separate driving elements mounted on a common magnetic structure and feeding separate horns.[13]

Theoretical and experimental studies were made of horns whose longitudinal sections are hyperbolic. Their driving-point impedances at low frequencies were found to be roughly twice those of conical horns having the same terminal dimensions.[15] It is interesting to note that by analogy the results can be applied to hyperbolic-tapered transmission lines.

MICROPHONES

There were substantial advances in the microphone field during the past year, both in telephone transmitters and devices intended primarily for broadcasting, public address, and recording applications.

Unidirectional microphones with a new operating principle were made available. Instead of employing a combination of pressure and velocity elements as was done previously, use was made of a phase-shifting acoustical network associated with a single diaphragm-type Rochelle-salt assembly.[16] The simplified structure provides a cardioid directivity pattern over the important range of the audible spectrum with a front-to-rear discrimination of the order of 15 decibels. The same principles were applied to a moving-coil microphone. A microphone with cardioid unidirectional characteristics is available in which the pressure element is a moving-coil unit and the pressure-gradient element is a ribbon-type velocity unit.[16] A specially formed relatively thick ribbon is used in the velocity element resulting in reduced susceptibility to air movements. The two elements are equalized by means of a built-in adjustable transformer and correction network. The average front-to-rear discrimination is about 20 decibels in the range from 50 to 8000 cycles.

Investigation of the finite size of directional microphones[17] was made, showing the effect on directivity.

An ultra-directional microphone of the line type,[18] using a bundle of tubes of progressive lengths, was developed. Several types of line microphones were described and include a simple line, a line with progressive delay, two simple lines and a pressure-gradient element, and two lines with progressive delay and a pressure-gradient element. An ultra-directional microphone was developed employing line elements and exhibits uniform directional characteristics over the range from 85 to 8000 cycles.

Renewed attention was given to the problem of screening microphones from gross air movements. A Bernouilli-type wind screen[19] was developed which takes advantage of the pressure and phase difference existing over the surface of a microphone to reduce the wind pressure effective at the diaphragm.

TELEPHONE INSTRUMENTS

There was a large improvement in sound-powered telephones not requiring an auxiliary power source for intercommunication service. One new feature of these telephones is the provision for a calling signal involving mechanical modulation of the magnetic circuit.[20]

A design of receiver was introduced in the United States for general telephone use[21] which has substantially uniform response up to about 3000 cycles, obtained partly by the added stiffness and damping of a shallow chamber behind the diaphragm with an acoustic resistance outlet. Appreciably higher magnetic efficiency was obtained without loss of stability.

The associated transmitter was improved so as to decrease aging in service, give more uniform response, reduce nonlinear distortion, and diminish the effect of angular position on the performance characteristics.

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[11] H. F. Olson, "Horn consisting of manifold exponential sections," *Jour. Soc. Mot. Pic. Eng.*, vol. 30, pp. 511–518; May, (1938).

[12] "Radio progress during 1937," Proc. I.R.E., vol. 26, p. 279; March, (1938).

[13] Frank Massa, "Horn-type loud speakers," Proc. I.R.E., vol. 26, pp. 720–733; June, (1938).

[14] Frank Massa, "Temperature reduction in high-powered loud speakers," *RCA Rev.*, vol. 3, pp. 196–202; October, (1938).

[15] V. Salmon, "Some measurements on a hyperbolic horn." Presented, Acoustical Society of America Meeting, November, 1938.

[16] "Microphone directivity by combination of ribbon and dynamic elements," Proc. I.R.E., vol. 27; p. x; January, (1939).

[17] Frank Massa, "Effect of physical size on the directional characteristics of unidirectional and pressure gradient microphones," Summary, *Jour. Acous. Soc. Amer.*, vol. 10, p. 85; July, (1938).

[18] H. F. Olson, "Line microphones," *Broadcast News*, no. 28, p. 32; July, (1938).

[19] W. D. Phelps, "Microphone wind screening," *RCA Rev.*, vol. 3, pp. 203–212; October, (1938).

[20] G. I. Atkins, "New magnetic telephone," *Bell Lab. Rec.*, vol. 16, pp. 282–284; April, (1938).

[21] W. C. Jones, "Instruments for the new telephone sets," *Bell Sys. Tech. Jour.*, vol. 17, pp. 338–357; July, (1938); *Trans. A.I.E.E.*, vol. 57, pp. 559–564; October, (1938).

A telephone receiver of improved response-frequency characteristics was developed in Europe.[22] This uses a concentric magnetic circuit and a formed lightweight diaphragm with an armature fastened at the center. Acoustic resistance is introduced in the form of a constricted passage between the cap and the diaphragm.

ELECTROMECHANICAL INSTRUMENTS

There were a number of important developments in high-fidelity phonograph pickups and recording equipment.

The trend in the design of high-fidelity magnetic pickups for lateral records was definitely toward extension of the reproduced frequency range, increased uniformity of response, very light needle pressure, and low needle-point impedance. Most of the new designs are characterized by relatively low output level.

A magnetic pickup for lateral reproduction with a response characteristic within ±3 decibels from 30 to 18,000 cycles was developed.[23] A sapphire-tipped stylus is employed which exerts a pressure of only 0.17 ounce (about 5 grams) on the record. Low needle-point impedance is attained by utilizing a very light, compliant, single-turn-loop conductor in the moving system.

A new pickup with a D'Arsonval-type moving-coil element[24] is now available. A permanent sapphire-tipped stylus is used which will operate with a needle pressures of 6 grams.

A new lateral pickup operating on the inductor principle was introduced.[25] The moving system embodies two small inductor poles separated by a compliance proportioned to give a rising response at low frequencies.

Improvements in lateral recorders and pickups were reported[26] which result in records for immediate playback in which the surface noise is 55 decibels below the maximum signal level. The response-frequency characteristic is substantially flat from 50 to 9000 cycles.

A phonograph reproducer was developed which employs two moving coils and a single stylus and can be used to reproduce either vertical or lateral recordings. The coils are fixed on a support which moves parallel to itself for vertical recording and which rocks for lateral recording. The vertical and lateral outputs are selected by altering the coil connections.

ACOUSTICS OF BROADCAST STUDIOS

Broadcast studios constructed during the last year have incorporated the use of serrated or V'd wall and ceiling surfaces to a greater extent to avoid discrete and persistent reflections and to provide a more diffuse sound field. The principle of providing essentially uniform acoustical conditions throughout the studio by the uniform distribution of absorbing material is being retained and in general the "live-end—dead-end" principle is being modified in this direction by providing some absorbent material in the "reverberant" area. Attention is being given to the possible use of resonant surfaces, such as furred-wood paneling to enhance the tonal qualities of orchestras, but information and experience available at this time do not permit formulation of an opinion as to its relative merits. Present trends indicate an increase in the number of auditorium studios in which provision is made for the accommodation of a relatively large studio audience. There were no outstanding or major changes in the design procedure of studios but rather a refinement, simplification, and improvement of present practices.[27–34]

MEASUREMENT APPARATUS AND TECHNIQUES

Revised standards on electroacoustics covering measuring apparatus and techniques and definitions of terms were published by the Institute of Radio Engineers.

Many aspects of the performance of loud speakers and microphones can be determined to best advantage by outdoor measurements. Because the weather places severe restrictions on outdoor measurements much attention was given to the problem of con-

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[22] H. Panzerbieter, "Stand der entwicklung von mikrophonen und telephonen für teilnehiwierapparate," *Elek. Zeit.*, vol. 59, pp. 550–553; May 26, (1938).

[23] F. V. Hunt and J. A. Pierce, "HP6A: A radical departure in phonograph pickup design," *Electronics*, vol. 11, pp. 9–12; March, (1938).

[24] G. W. Downs, Jr. and W. Miller, "D'Arsonval reproducer for lateral recordings," *Communications*, vol. 18, pp. 19–35; October, (1938).

[25] " 'Two-channel' pickup," *Communications*, vol. 18, p. 41; June, (1938).

[26] H. J. Hasbrouck, "A new high-fidelity reproducer for lateral disk records." Presented, I.R.E. Convention, New York, N. Y., June 17, 1938. PROC. I.R.E., this issue, pp. 184–187.

[27] J. R. Powers, "Measurement of absorption in rooms with sound absorbing ceilings," *Jour. Acous. Soc. Amer.*, vol. 10, pp. 90–101; October, (1938).

[28] C. J. Marreau, "The insulation of air-borne sounds," *Jour. Acous. Soc. Amer.*, vol. 10, pp. 45–49; July, (1938).

[29] Paul E. Sabine, "Effects of cylindrical pillars in a reverberation chamber," *Jour. Acous. Soc. Amer.*, vol. 10, pp. 1–5; July, (1938).

[30] J. McLaren, "Acoustical design of broadcasting studios," *World-Radio*, vol. 26, pp. 14–15; May 6, (1938).

[31] J. McLaren, "Acoustics in broadcasting studio design," *World-Radio*, vol. 26, July 23, (1938).

[32] M. Rettinger, "Scoring-stage design," *Jour. Soc. Mot. Pic. Eng.*, vol. 30, pp. 519–534; May, (1938).

[33] J. P. Maxfield, A. W. Colledge, and R. T. Friebus, "Pickup for sound motion pictures," *Jour. Soc. Mot. Pic. Eng.*, vol. 30, pp. 666–679; June, (1938).

[34] John McLaren, "Broadcasting House, Glasgow," *World-Radio*, vol. 27, November 25, (1938).

structing suitable test rooms in which free-field conditions are approached as closely as possible. Tests on rooms of this type indicated that the microphone must be kept relatively near the sound source. In one room, employing a multiple-layer cloth boundary, pressure differences of the order of one decibel in a small frequency interval were observed.[35] A test room having a large number of closely spaced sound-absorbing panels mounted normal to the walls was investigated and approximately an inverse-distance—pressure relationship observed up to a distance of two meters from the sound source.[36] for frequencies between 50 and 10,000 cycles.

An oscillator and an analyzer, each of which employs reverse feedback in combination with a resistance-capacitance network were made available.[37]

Electronic Musical Instruments

A versatile electronic musical instrument was introduced in which the wave-envelope shape and harmonic content can be varied over wide limits. All the needed frequencies are derived from twelve high-frequency oscillators by a cascade frequency divider in which the frequency is halved in each stage. The overtone structure of each note is made a function of the input level by the use of an overbiased nonlinear amplifier.

Some disadvantages of mechanoelectrical transducers employing electrostatic pickups with direct polarizing voltages were overcome in a newly developed system in which the capacitance change frequency-modulates a low-powered radio-frequency oscillator. This system was employed in a combination electronic piano and radio receiver in which economies were effected by using the radio receiver to demodulate the frequency-modulated signal.

Electrostatic pickup signal-generating means were extended to guitar, music-box carillons, violins, and double-bass violins which were demonstrated.

An electronic instrument employing a piano scale was developed in which the string length is one third, the aggregate string tension one twentieth, and the number of strings one half those of a conventional piano.

Further refinements were made in electrically amplified chimes. The acoustic output of chimes employing electrically actuated strikers is picked up and amplified by a microphone and amplifier. Directive horn-type loud speakers are employed to give high efficiency, and confine the radiation to the desired solid angle.

This report was prepared under the supervision of the Annual Review Committee by the Technical Committee on Electroacoustics of the Institute of Radio Engineers, the personnel of which follows.

H. S. Knowles, Chairman
L. B. Blaylock *George Nixon*
J. T. L. Brown *Benjamin Olney*
R. P. Glover *H. F. Olsen*
Knox McIlwain *Hans Roder*
L. J. Sivian

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[35] G. S. Cook, "Field calibration of microphones," abstract, *Jour. Acous. Soc. Amer.*, vol. 10, p. 86; July, (1938).

[36] W. Janovsky and F. Spandock, "Aufbau und untersuchung eines schallgedampten Ranmes," *Akust. Zeit.*, vol. 2, pp. 332–341; November, (1937).

[37] H. H. Scott, "A new type of selective circuit and some applications," Proc. I.R.E., vol. 26, pp. 226–235; February, (1938).

PART II—ELECTRONICS*

This portion of the report describes developments in electronics under the following divisions: cathode-ray and television tubes, ultra-high-frequency tubes, receiving tubes, transmitting tubes, gas tubes, and photoelectric devices.

Cathode-Ray and Television Tubes

Television pickup tubes of the iconoscope type were made more sensitive by improved processing and by the use of illumination on the bulb wall, the spectral sensitivity was made similar to that of the human eye, and internal reflections were reduced by roughening the mosaic.[1] A form of iconoscope in which the photosensitive surface and the storage mosaic are separated was reported.[2] The investigation of photoconductive materials for use in television transmission continued.[3] Dissector tubes were designed especially for the transmission of motion pictures,[4] and an image amplifier pickup tube was introduced which attains high sensitivity through the use of a photosensitive picture-storage grid acting also as a control grid to produce an amplified signal in the scanning operation.[5]

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* Decimal classification: R330×621.375.1.

[1] R. B. Janes and W. H. Hickok, "Recent improvements in the design and characteristics of iconoscopes." Presented, I.R.E. Convention, New York, N. Y., June 17, 1938. Summary, Proc. I.R.E., vol. 26, p. 668; June, (1938).

[2] Harley Iams, G. A. Morton, and V. K. Zworykin, "The image iconoscope." Presented, I.R.E. Convention, New York, N. Y., June 17, 1938. Summary, Proc. I.R.E., vol. 26, p. 668; June, (1938).

[3] H. Miller and J. W. Strange, "Electrical reproduction of images by the photoconductive effect," *Proc. Phys. Soc.*, vol. 50, pp. 374–384; May 2, (1938).

[4] C. Larson and B. C. Gardner, "Production of image dissector tubes for motion picture pickup." Presented, Rochester Fall Meeting, Rochester, N. Y., November 16, 1938.

[5] P. T. Farnsworth and B. C. Gardner, "Image amplifier pickup tubes." Presented, Rochester Fall Meeting, Rochester, N. Y., November 14, 1938.

The theory of cathode-ray television tube operation was extended for the iconoscope type,[6–8] as well as for the photoconductive type and for the semiconducting dielectric type.[9]

The monoscope,[10] which is a fixed television image-generating tube, has been added to the useful tools for television development work.

The understanding of the behavior of electron multipliers was advanced,[11] and the design tended toward the use of constant voltages and electrostatic focusing between stages. The improved design gave greater stability and required less auxiliary apparatus. The development of such multipliers was aided by the use of rubber-membrane electron-path plotters.[12,13]

Tubes for direct viewing of television pictures were made shorter to permit horizontal mounting in the cabinet; the short tubes usually used magnetic deflection. Most of the fluorescent screens were white or near-white. Research relative to the properties of fluorescent materials gave added information on the control of color,[14] causes of discoloration,[15] and possibility of operating at higher anode voltages in order to get increased light.[16] In cathode-ray tubes the contrast between bright and dark parts of the picture was found to be limited primarily by halation effects occurring within the glass face of the tube, and ways to increase the contrast were proposed.[17]

The trend in television projection tubes was toward the use of higher anode voltages (20,000 to 50,000 volts).

Further studies have been made of electron guns and other design factors for projection tubes.[18]

Theoretical studies of "detail contrast," "gamma," and other qualities of the television image in terms of the properties of the scanning spot, were extended.[19–21]

The development of television tubes was aided by further advances in the field of electron optics. Also the increased knowledge was applied to the design of electron microscopes, some of which attained an over-all linear magnification of 100,000, a magnification far greater than that which can be used advantageously with visible light. In some microscopes the specimens, mounted on collodion film, were irradiated with 100,000-volt electrons and the transmitted electrons were focused upon a fluorescent screen by magnetic electron lenses.[22]

A cathode-ray tube particularly suitable for measuring magnetic fields was developed.[23]

ULTRA-HIGH-FREQUENCY TUBES

The developments in ultra-high-frequency vacuum tubes have produced noteworthy improvements in tubes where the electron transit-time is a small fraction of the oscillating period.

Receiving tubes showed marked increase in the ratio of transconductance to input admittance and the development[24] of a single-stage, oxide-coated thermionic cathode, electron multiplier. Improvements in pentode amplifier tubes resulted in the attainment of a transconductance of 9000 micromhos with attendant smaller increase in input admittance.[25] Thermionic oxide-coated-cathode multiplier tubes used previously resulted in a secondary emitting surface which was adversely affected by deposits evaporated from the primary cathode. Since the evaporated molecules leave the cathode in practically straight lines, baffles were interposed between the primary and secondary cathodes and a suitable

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[6] V. K. Zworykin and others, Discussion on "Theory and performance of the iconoscope," *Jour. I.E.E.* (London), vol. 82, pp. 561–562; May, (1938).

[7] W. Heimann and K. Wemheuser, "Contribution to the explanation of the action of the electron-beam picture scanner," *Elek. Nach. Tech.*, vol. 15, pp. 1–9; January, (1938).

[8] W. Heimann, "Electronics television pickup tubes," *Funktech. Monatshefte*, no. 8, supplement, pp. 59–63; August, (1938).

[9] G. Krawinkel, W. Kronjager, and H. Salow, "On a light storing television camera with semiconductive dielectric," *Zeit. für Tech. Phys.*, vol. 19, no. 3, pp. 63–73; (1938).

[10] C. E. Burnett, "The monoscope," *RCA Rev.*, vol. 2, pp. 414–420; April, (1938).

[11] W. Shockley and J. R. Pierce, "A theory of noise for electron multipliers," PROC. I.R.E., vol. 26, pp. 321–332; March, (1938).

[12] J. R. Pierce, "Electron multiplier design," *Bell Lab. Rec.*, vol. 16, pp. 305–309; May, (1938).

[13] V. K. Zworykin and J. A. Rajchman, "Electrostatic electron multiplier." Presented, I.R.E. Convention, New York, N. Y., June 17, 1938. Summary, PROC. I.R.E., vol. 26, p. 677; June, (1938).

[14] H. W. Leverenz, "Relative emission spectra of zinc silicates and other cathodoluminescent materials," *Phys. Rev.*, vol. 53, pp. 919–920; June, (1938).

[15] C. H. Bachman and C. W. Carnahan, "Negative-ion components in the cathode-ray beam," PROC. I.R.E., vol. 26, pp. 529–539; May, (1938).

[16] K. Scherer and R. Rubsaat, "Brightness measurements on zinc-sulfide screens excited by cathode rays," *Arch. für Elek.*, vol. 31, pp. 821–826; December, (1937).

[17] R. R. Law, "Contrast in kinescopes." Presented, I.R.E. Convention, New York, N. Y., June 17, 1938. Summary, PROC. I.R.E., vol. 26, p. 669; June, (1938).

[18] E. Schwartz, H. Strubig, and H. W. Paehr, "Ray generation in television tubes for projection purposes," *Zeit. der Fernsehen A. G.*, vol. 1, pp. 5–13; August, (1938).

[19] L. C. Jesty and G. T. Winch, "Television images: an analysis of their essential qualities," *Jour. Telev. Soc.*, vol. 2, pp. 316–334; December, (1937).

[20] Kollner, Mertz, and Gray, "On the analysis and synthesis of a television picture," *Telefunken*, vol. 19, pp. 46–60; March, (1938).

[21] H. A. Wheeler and A. V. Loughren, "The fine structure of television images," PROC. I.R.E., vol. 26, pp. 540–575; May, (1938).

[22] "Electron microscopes," *Electronics*, vol. 11, pp. 30–33; November, (1938).

[23] Albert Rose, "An electronic device for measuring magnetic fields," *Electronics*, vol. 11, pp. 21, 53, 54; July, (1938).

[24] J. L. H. Jonker and A. J. W. M. van Overbeek, "The application of secondary emission in amplifying valves," *Wireless Eng.*, vol. 15, pp. 150–156; March, (1938).

[25] A. P. Kauzman, "New television amplifier receiving tubes." Presented, Rochester Fall Meeting, Rochester, N. Y., November 16, 1938.

electric field provided to deflect the primary electrons around the baffles. These improvements resulted in the development of a single-stage multiplier having a transconductance of about 14,000 micromhos. The input conductance is reduced because only the small primary cathode current causes grid loading. Measurments were reported[26,27] and theory developed to show that the high-frequency effects of self and mutual admittances of tube electrodes and leads account for a considerable part of the input damping formerly ascribed to transit-time effects. Recent studies of the theory of electron inertia[28] indicates that second-harmonic damping of the grid circuit becomes important at relatively low input signals. Theoretical work[29] on diodes showed that internally generated noise decreases as the electron transit-angle increases. Negative-resistance characteristics were observed[30,31] in the outer grid of converter tubes which have a useful order in the region of 15 to 300 megacycles. With this characteristic an external signal can be mixed with an internally generated high-frequency voltage to produce stable converter action.

The effects of excess-energy electrons on magnetron cutoff characteristics and on cathode bombardment have been discussed in detail.[32,33] These investigations explain the instability of magnetrons as being partially attributable to random electron velocities superimposed on the orbital velocities in such manner that some electrons gain energy. This leads to the formation of a new type of virtual cathode around the real cathode and theory is developed on this basis to account for the conditions observed.

Advances in magnetron development show a marked increase in the maximum frequency obtained. The limit of transit-time magnetron oscillations[34] has been extended to a frequency of 61,000 megacycles. An output of 2.5×10^{-7} watt was obtained with an input of 2.4 watts. Amplitude modulation of these magnetrons was accomplished but a frequency modulation of approximately 2 per cent also occurred.

Sectionalized magnetrons[35] were described in which efficiencies up to 70 per cent were obtained at frequencies above 300 megacycles. Typical operation at 500 megacycles developed an output of 100 watts at 50 per cent efficiency. Magnetrons with several anode sections[36] and the cathode located at one or both ends of the anode were described. Efficiencies up to 40 per cent were obtained at a frequency of 600 megacycles with an output of 10 watts. Special forms of this magnetron[37] produced an output of 20 watts at a frequency of 2000 megacycles with an efficiency of 50 per cent.

Magnetrons of 8 to 12 anode segments were employed[38] to produce oscillations dependent on the electron transit-time between segments as defined by the distance traveled by the electrons at the periphery of the orbits. At a field strength of 500 gausses (obtained by a permanent magnet) and an anode voltage of only 700 volts, an output of 10 watts was obtained at 2000 megacycles with an efficiency of 15 per cent. An output of 6 watts could be obtained at 3000 megacycles.

A push-pull type of positive-grid tube[39] was described in which modulation may be attained with practically no variation in frequency as compared to previous tubes of this type. The data described are for only one case where an efficiency of 4 per cent was obtained at 300 megacycles.

Theoretical considerations of electron transit-time effects were treated in several papers.[40–42] Previous considerations dealt mainly with class A amplifier conditions. A transit-time rectifier[40,41] was described in which an alternating anode voltage is transformed into a direct-current component in the grid circuit. Theory was also developed[42] relative to the phenom-

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[26] M. J. O. Strutt and A. van der Ziel, "The cause for the increase of the admittance of modern high-frequency amplifier tubes on short waves," Proc. I.R.E., vol. 26, pp. 1011–1032; August, (1938).

[27] M. J. O. Strutt and A. van der Ziel, "The behavior of amplifier valves at very high frequencies," *Philips Tech. Rev.*, vol. 3, pp. 103–111; April, (1938).

[28] W. E. Benham, "A contribution to tube and amplifier theory," Proc. I.R.E., vol. 28, pp. 1093–1170; September, (1938).

[29] A. J. Rock, "Effect of space charge and transit time on the shot noise of diodes," *Bell Sys. Tech. Jour.*, vol. 17, pp. 592–619; October, (1938).

[30] J. R. Nelson, "Input impedance of converter tubes." Presented, I.R.E. Convention, New York, N. Y., June 16, 1938. Summary, Proc. I.R.E., vol. 26, pp. 671–672; June, (1938).

[31] M. J. O. Strutt, "The characteristic admittances of mixing valves for frequencies up to 70 megacycles," *Elek. Nach. Tech.*, vol. 15, pp. 10–17; January, (1938).

[32] E. G. Linder, "Effect of high energy electron random motion on the shape of the magnetron cutoff curve," *Jour. App. Phys.*, vol. 9, pp. 331–334; May, (1938).

[33] E. G. Linder, "Excess-energy electron and electron motion in high-vacuum tubes," Proc. I.R.E., vol. 26, pp. 346–371; March, (1938).

[34] H. Richter, "The generation of centimeter and millimeter waves in a magnetron." *Hochfrequenz. und Elek.*, vol. 51, pp. 10–17; January, (1938).

[35] K. Owaki and T. Suzuki, "Sectionalized magnetron," *Electrotech. Jour.* (Japan), vol. 2, pp. 257–260; November, (1938).

[36] S. Uda, H. Ultida, and H. Sekimoto, "On the new vacuum tubes 'sentron' for ultra-short waves," *Nippon Elec. Comm. Eng.*, pp. 171–177; April, (1938).

[37] S. Uda, M. Ishida, and S. Sioji, "Ultra-high-frequency oscillations obtained by 'sentron' tubes," *Electrotech. Jour.* (Japan), vol. 2, pp. 266–267; November, (1938).

[38] H. Gutton and S. Berlin, "Production of large power at decimeter wavelengths," *Jour. de Phys. et le Radium*, vol. 9, supplement, pp. 10–11; January, (1938).

[39] S. Nakamura, "Electron oscillations produced by a thermionic tube with plane electrodes operated in push-pull," *Nippon Elec. Comm. Eng.*, no. 10, pp. 134–139; April, (1938).

[40] K. S. Knol, M. J. O. Strutt, and A. van der Ziel, "Motion of electrons in an alternating electric field," *Physica*, vol. 5, pp. 325–334; May, (1938).

[41] M. J. O. Strutt, "Electron transit time effects in multigrid valves," *Wireless Eng.*, vol. 15, pp. 315–321; June, (1938).

[42] M. R. Gavin, "Electron pump effect at high frequencies," *Wireless Eng.*, vol. 15, pp. 81–83; February, (1938).

encn that electron current may flow to the anode of a triode when a high-frequency alternating voltage is applied to the grid and a negative voltage to the anode. Measurements on tubes at ultra-high frequencies provide a check of the theoretical treatments of electron transit-time effects.[43]

"Phase focusing"[44] of electrons in rapidly changing electric fields were discussed and general theoretical considerations developed on this new principle which may be of considerable value in predicting the effect of "electron lumping." The treatment shows that the analogy of electron optics may be applied. It is shown that slow and fast electrons are "focused" into groups by proper arrangement of the electric fields both from the geometric and dynamic standpoints.

A new type of high-Q tank circuit for use at frequencies in the order of 2000 megacycles was developed[45] whereby the efficiency of magnetrons or positive-grid oscillator tubes may be increased materially. At 2000 megacycles an output of 2 watts with an efficiency of 7 per cent was obtained.

A coaxial-line-stabilized oscillator[46] that is easily and rapidly adjustable over a frequency range from 70 to 700 megacycles was developed for application to small negative-grid tubes. This circuit may be applied to increase the stability of oscillations so that modulation may be attained with a frequency variation in the order of 100 parts in a million.

From the application standpoint, negative-grid tubes continue to hold the greatest interest. Extension of molded-glass technique has been applied to an increasing number of tubes since its introduction in 1935. This has made possible the machine production of tube structures previously realized only by hand construction. The availability of these tubes has led to numerous applications such as a direct-reading terrain-clearance indicator which operates by the reflection of ultra-high-frequency waves. A push-pull beam tetrode[47] having an upper frequency limit of 300 megacycles and which will deliver its full power of 22 watts at 150 megacycles was developed. This tube is similar in many respects to one described previously[48] but has the additional features of a beam power tube. Internal shielding eliminates the need for neutralizing in properly designed circuits.

RECEIVING TUBES

Standards on electronics were issued by the Institute of Radio Engineers and include definitions of terms, symbols, and tests for various types of tubes.

The year was noteworthy for the introduction of converter tubes giving improved performance especially at high frequencies, of single-ended radio-frequency tubes, of battery tubes giving more economical performance, and for reduction of tube size.

Refinement of fundamental theory is evidenced by papers on space charge,[49,50] a discussion of the theory of tubes having very close grid-cathode spacing,[51] and articles dealing with fluctuation noise caused by current distribution in multielectrode tubes.[52,53] Further studies of the effects of lead inductance and coupling between leads were reported.[26] More attention was paid to the reduction of the effects caused by variation of input capacitance of tubes with application of automatic-volume-control voltage.[54]

Improvements in frequency-converters, lead to greater oscillator frequency stability and improved high-frequency performance.[55–58] Beam principles were employed to prevent electrons returned by a second control grid from entering the region around the first control grid and, thus, provided improved frequency stability. Measurements of converter operation at high frequencies led to a better understanding of converter design.[30,31]

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[43] M. J. O. Strutt and A. van der Ziel, "Measurements of the complex steepness of modern multigrid valves in the short-wave region," *Elek. Nach. Tech.*, vol. 15, pp. 103-111; April, (1938).

[44] E. Prüche and A. Rechnagel, "Phase focusing of electrons in rapidly fluctuating electric fields," *Zeit. für Phys.*, vol. 108, nos. 7–8, pp. 459-482; (1938).

[45] A. Allerding, W. Dällenbach, and W. Kleinsteuber, "The resotank, a new generator for microwaves," *Hochfrequenz. und Elektroakustik*, vol. 51, pp. 96-99; March, (1938).

[46] W. L. Barrow, "An oscillator for ultra-high frequencies," *Rev. Sci. Instr.*, vol. 9, pp. 170–174; June, (1938).

[47] A. K. Wing, "A push-pull ultra-high-frequency beam tetrode." Presented, I.R.E. Convention, New York, N. Y., June 16, 1938. Summary, PROC. I.R.E., vol. 26, pp. 676–677; June, (1938).

[48] A. L. Samuel and N. E. Sowers, "A power pentode for ultra-high frequencies," PROC. I.R.E., vol. 24, pp. 1464–1483; November, (1936).

[49] C. E. Fay, A. L. Samuel, and W. Shockley, "On the theory of space charge between parallel plane electrodes," *Bell Sys. Tech. Jour.*, vol. 17, pp. 49–79; January, (1938).

[50] B. Salzberg and A. V. Haeff, "Effect of space charge in the grid-anode region of vacuum tubes," *RCA Rev.*, vol. 2, pp. 336–374; January, (1938).

[51] L. Oertel, "On the theory of valves whose grid-cathode spacing is smaller than the pitch of the grid," *Telefunken Röhre*, no. 12, pp. 7–17; April, (1938).

[52] C. J. Bakker, "Current distribution in multi-electrode radio valves," *Physica*, vol. 5, pp. 581–592; July, (1938).

[53] W. Schottky, "On the theory of electron noise in multiple grid valves," *Ann. der Phys.*, vol. 32, pp. 195–204; May, (1938).

[54] R. L. Freeman, "Use of feedback to compensate for vacuum-tube input-capacitance variations with grid bias," PROC. I.R.E., vol. 26, pp. 1360–1366; November, (1938); *Wireless World*, vol. 43, p. 340; October 13, (1938).

[55] E. W. Herold, T. J. Henry, and W. A. Harris, "A new converter tube for all-wave receivers," *RCA Rev.*, vol. 3, pp. 67–77; July, (1938).

[56] "Improved converter tube," *Radio Retailing*, vol. 23, pp. 67–68; January, (1938).

[57] W. A. Harris, "A single-ended pentagrid converter." Presented, Rochester Fall Meeting, Rochester, N. Y., November 15, 1938.

[58] J. L. H. Jonkers, "A new converter valve," *Wireless Eng.*, vol. 15, p. 423; August, (1938).

A large number of new types of tubes was described or released in addition to the converter types noted above. From Europe, an amplifier tube having a thermionic cathode and obtaining amplification by secondary emission is of interest.[24] A tube employing screen and suppressor grids of variable-pitch windings to reduce screen current and, consequently, noise was made available abroad.[59,60] A line of glass tubes was introduced in the United States and elsewhere in which the lead-in wires are used as base pins[61] which fit a special socket designed to lock the tube in place. Single-ended tubes eliminating the top cap were introduced both in metal and glass construction mentioned above. A new line of battery tubes operating with filament current of only 50 milliamperes and designed for use on a 1.5-volt dry battery without series resistor was made available. Three new acorn tubes of low-drain filament type also designed for 1.5-volt dry-battery operation and intended for compact designs of ultra-high-frequency equipment were announced. New high-transconductance pentodes,[62,63] although made available primarily for television purposes, found considerable use in other receiving equipment. An electron-ray tube[63] for tuning-indicator purposes is available with 2 control electrodes to permit a double indication and provide a vernier action.

TRANSMITTING TUBES

Advances in large high-vacuum tubes were chiefly in the extension of high-frequency operation and in the introduction of beam-type pentodes of larger power output.

GAS TUBES

The field of gas-filled tubes has been characterized chiefly by the introduction of a number of new trigger and relay tubes for various control functions in radio systems.

The dynamic characteristics of several glow-discharge tubes were studied by Reich and Depp,[64] using a method of controlled current flow and observing with a cathode-ray oscillograph. They show that the static curves do not indicate the behavior of such tubes under dynamic conditions because of the time interval required for ionization and deionization, the voltage at any instant depending upon the current flowing at that time, the current which has flowed previously, and upon the rate of change of current.

Two low-voltage triodes of the hot-cathode type,[65,66] were introduced for the remote control of apparatus, such as, broadcast receivers and the radio control of model planes and boats. One is argon-filled and is particularly useful where constancy of characteristics is necessary with large variations in ambient temperature. The other is designed for use as a self-quenching superregenerative detector which upon the reception of a radio signal will operate a high-resistance relay in the anode circuit.

Gas tubes in which the discharge is controlled by an external magnetic field rather than by an internal grid were made available.[67] These tubes contain a cathode, an anode, and an electrode, termed the "collector," placed between the cathode and anode. In operation, a transverse magnetic field is applied to the tube, deflecting to the "collector" electrons emitted by the cathode. This field inhibits the ionization by preventing the passage of electrons at high velocity to the anode. One of the advantages of this type of tube is that the control circuit may be kept electrically insulated from the work circuit.

Voltage-stability requirements for devices such as oscillators used in modern broadcast receivers revived interest in voltage-regulator tubes and resulted in the introduction of three new gas diode types.

Service reports on hot-cathode mercury-vapor tubes, used in supplying the high direct voltage for radio transmitting equipment, are showing extraordinary life. It is now a common occurrence for such tubes to give service in excess of 20,000 hours and in one instance a life exceeding 44,000 hours was reported.

PHOTOELECTRIC DEVICES

There was an increase in the use of small phototubes in 16-millimeter sound movie equipment.

Improved designs of the photoelectric multiplier have been described.[68,69] By the use of the rubber-membrane types of field-plotting equipment, the electrodes were so modified that good focusing is obtainable without a magnetic field, thereby increasing flexibility in use.

In television pickup tubes, improved sensitivity

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[59] C. Kerger, "New valves for the broadcasting year 1938/39," *Funktech. Monatshefte*, no. 8, pp. 233–244; August, (1938).

[60] *Telefunken Röhre*, supplement, no. 13; August, (1938).

[61] "The wireless exhibition, 1938," *Wireless Eng.*, vol. 15, p. 552; October, (1938).

[62] A. P. Kauzmann, "New television amplifier receiving tubes." Presented, Rochester Fall Meeting, Rochester, N. Y., November 16, 1938.

[63] "New Products," *Electronics*, vol. 11, p. 58; July, (1938).

[64] H. J. Reich and W. A. Depp, "Dynamic characteristics of glow-discharge tubes," *Jour. App. Phys.*, vol. 9, pp. 421–426; June, (1938).

[65] "New gear for radio-control systems," *QST*, vol. 22, pp. 44–45; July, (1938).

[66] C. B. DeSoto, "Radio control of powered models," *QST*, vol. 22, pp. 24–44; October, (1938).

[67] "The Permatron—a new type of rectifier with magnetic control," *QST*, vol. 22, pp. 42, 86, 88; September, (1938).

[68] V. K. Zworykin and J. A. Rajchman, "Electrostatic electron multipliers." Presented, I.R.E. Convention, New York, N. Y., June 17, 1938. Summary, PROC. I.R.E., vol. 26, p. 677; June, (1938).

[69] J. R. Pierce, "Electron multiplier design," *Bell Lab. Rec.*, vol. 16, pp. 305–309; May, (1938).

and better match to the response of the eye were obtained by the careful control of the caesium-to-oxygen ratio of the photoelectric surface. The use of an evaporated metallic layer upon the sensitized surface results in a modification of the spectral sensitivity to give a closer approach to the response of the eye.[1]

A "positive" barrier or blocking-layer photoeffect was reported which is produced by suitably treating thallium sulphide.[70] Preliminary measurements give a sensitivity of 5000 to 6000 microamperes per lumen, which is approximately 10 times the sensitivity of a selenium blocking-layer cell. In the new cell, the electrons are thought to pass from the metal into the semiconductor. Several papers were published about a photosensitive surface which was reported to have a high selective sensitivity to blue lights.[71,72] The surface consists of an alloy of caesium with bismuth or antimony. A selective maximum is found at about 4500 ångstroms with the long-wavelength limit at 6100 ångstroms. These references also report a small shift to a longer wavelength of the maximum of the curves by addition of oxygen, and an increased red response by the deposition of the surface upon the well-known caesium—caesium-oxide—silver surface.[73,74] The peak of the selective effect is broadened to include more of the visible spectrum. This does not greatly increase the response to tungsten light but improves the fidelity when used for scanning.

Further measurements on the inertia effect in gas-filled phototubes were reported stating a dependence upon the geometrical construction (finite time for the passage of gas ions)[75] as well as upon secondary phenomena occurring at the cathode surface at the impact of the positive ion.[76] Several years' work on the correlation between the optical properties of thin films of alkali metals with their respective photoelectric emission were reported.[77,78]

This report was prepared under the supervision of the Annual Review Committee by the Technical Committee on Electronics of the Institute of Radio Engineers, the personnel of which follows.

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[70] B. Kolomiez, "New 'positive' barrier photoelectric effect and the new barrier-plane photocell," *Comp. Rend. (Doklady) de l'acad. des Sci. U.S.S.R.*, vol. 19, no. 5, pp. 383–384; (1938).

[71] P. I. Lukirski and N. N. Lusheva, "Photocells with a highly selective sensitivity," *Jour. Tech. Phys.*, vol. 7, no. 18/19, pp. 1900–1904; (1937).

[72] P. Gorlich, "Measurements on photocathodes in contact," *Phil. Mag.*, vol. 25, p. 256; February, (1938).

[73] P. Gorlich, "Transparent photocathodes," *Zeit. für Tech. Phys.*, vol. 18, no. 11, pp. 460–462; (1937).

[74] P. Gorlich, "Measurements at composite photocathodes," *Zeit. für Phys.*, vol. 109, no. 5/6, pp. 374–386; (1938).

[75] A. M. Skellett, "Time lag in gas-filled photoelectric cells," *Bell Lab. Rec.*, vol. 16, pp. 321–323; May, (1938).

[76] G. P. Belgovski, "Inertia in gas-filled photocells." *Jour. Tech. Phys.*, vol. 7, no. 14, pp. 1462–1467; (1937).

[77] H. B. Briggs and H. E. Ives, "Optical constants of rubidium and caesium," *Jour. Opt. Soc. Amer.*, vol. 27, pp. 395–400; November, (1937).

[78] H. E. Ives and H. B. Briggs, "Correlation of optical properties and photoelectric emission in thin films of alkali metals," *Jour. Opt. Soc. Amer.*, vol. 28, pp. 176–177; May, (1938).

PART III—RADIO RECEIVERS*

Although greatest interest is evident in the development of broadcast receivers, this section treats communication (point-to-point) and navigational-aid receivers as well. Information on measuring apparatus and techniques is included.

BROADCAST RECEIVERS

The impetus given the development of convenient tuning systems for the use of broadcast listeners during 1937 resulted in the almost universal adoption by American and European manufacturers in 1938 of some form of push-button tuning.[1–4] In many models the tuning dial was completely eliminated and from 4 to 20 channels were made available by push-button operation.[5] A larger proportion of receivers than in recent years was designed to operate in the standard broadcast band only.

Push-button tuning systems continue to be made in three classifications: first, those types in which the tuning condenser is rotated to a predetermined point by manually operated mechanical means; second, those types in which the gang condenser is driven to the predetermined point by a motor; and third, those types in which preset tuned circuits are selected directly or by the operation of relays.

Push-button control for preset tuned circuits has been extended so that it may include wave band, tone control, and on-off switching as well as other

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* Decimal classification: R360.

[1] "What's new in radio sets," *Electronics*, vol. 11, pp. 9–13, 55; August, (1938).

[2] "The Berlin show," *Wireless World*, vol. 43, p. 147; August 18, (1938).

[3] "Olympia show report," *Wireless World*, vol. 43, p. 172; August 25, (1938).

[4] "Olympia show review," *Wireless World*, vol. 43, p. 207; September 1, (1938).

[5] "Recent developments in push-button tuning," *Communications*, vol. 18, pp. 18–19; March, (1938).

special features. Manufacturers of component parts have made available improved switch gangs easily adaptable to various requirements. The use of latching mechanisms which automatically release buttons previously operated is general. One alternative type provides for sequential operation of the buttons.

Clock-controlled switching in connection with the new push-button receivers has appeared. One type automatically selects any one of five desired preset stations for the 15-minute broadcast periods during the entire 24-hour day.[6] Others permit preselection over the seven-day week.

There were further improvements in the stability of circuit components to minimize frequency variations caused by temperature and humidity fluctuations. Small fixed condensers with temperature coefficients which compensate for variations in other circuit elements are available. These usually employ special ceramic insulation having the required temperature coefficient, but liquid-filled units are also available. Several manufacturers supply unusually stable fixed mica condensers with sprayed-silver electrodes.

Preset tuning circuits utilize either adjustable condensers or adjustable inductances, or a combination of both. Combinations of adjustable iron-dust-core inductances with silver-on-mica fixed condensers for oscillator circuits, where the greatest stability is required, and adjustable condensers with fixed coils for radio-frequency circuits are used by several manufacturers.

Mechanical designs of adjustable condensers were improved so that smaller aging effects are noted. Ganged adjustable mica-condenser pairs for oscillator and radio-frequency preset circuits with means for correcting for small differences in capacitance are used in some receivers. Inductances with iron-dust cores are used with either individual or ganged adjustments.

Remote-control devices using multiconductor cables were designed to operate with all of the above types of automatic tuning. In some cases solenoids were used to operate the push buttons at the receiver through the remote-control circuit.

Another type uses a special low intermediate frequency and has radio-frequency circuits and a frequency changer at the remote unit. The intermediate-frequency signal is transmitted over the lighting circuit to a special main unit which may have any desired detector and audio-frequency system. Volume control is by means of a manual attenuator which is used to adjust the level of the intermediate-frequency signal applied to the line. On-off switching for the main unit is provided by means of special control oscillations from the remote unit transmitted over the lighting circuit when needed. These impulses operate suitable relays at the main unit.

A significant departure from past practice of possible future importance was the use of weak radiated fields generated locally to operate control devices or to supply modulated signals to the antenna circuits of standard receivers. In connection with these devices in the United States, the Federal Communications Commission tentatively ruled that radiating devices which utilize a low-power radio field will not require license if the strength of this field does not exceed 15 microvolts per meter at a distance from the source equal to the wavelength of the radiation divided by 2π.

A battery-operated remote-control unit of this type which radiates a low-power inductive field when a control impulse is required was introduced.[7] These control impulses actuate step switches through tuned circuits and relay tubes at the receiver. Newly developed gas-filled tubes are utilized in this system. The operations performed are station selection, volume control, and power switching. The frequency of the control impulse is in the band between 350 and 400 kilocycles. Special circuits reduce the probability of the operation of the step switches by extraneous noise. Control units are factory-adjusted to work with particular receivers.

Another type of remote control uses a frequency changer at the control unit radiating an intermediate frequency within the range of the standard broadcast band. The signal is picked up by an ordinary receiver through its antenna circuit.

Record players using a modulated oscillator to radiate a low-power field at a frequency just within the standard broadcast band and which may be received by near-by standard receivers appeared.

Battery receivers in the United States are largely confined to use in unwired homes and are now designed with a complete line of 1.4-volt low-drain tubes.[8] These tubes are available with single- and double-purpose functions similar to those of tubes ordinarily used in power-operated receivers. Portable battery receivers continue to be popular in Europe[9] and are finding increasing use in the United States.

There were no major changes in motorcar receivers except to follow the general trend in push-

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[6] D. R. De Tar, "Radio program preselector," *Electronics*, vol. 11, pp. 16–17; November, (1938).

[7] R. G. Herzog, "Mystery control," *Communications*, vol. 18, pp. 20–21, 29 and 31; October, (1938).

[8] Paul Marsal, "Battery radio design," *Electronics*, vol. 11, pp. 12–14; January, (1938).

[9] "Battery portables of 1938," *Wireless World*, vol. 42, p. 289; March 31, (1938).

button tuning. Solenoid-type remote-control devices were also produced for a few motorcar receivers.

The development of automatic-tuning and remote-control devices stimulated the manufacture of many new types of relays.[10]

Cabinets for small receivers are largely of molded plastics.[11] Die castings were greatly improved in permanence, in dimensional tolerances, and in strength, and are used for a large number of special parts.[12]

Phonograph-record players, both separate and in combination with radio receivers, became more popular. For these piezoelectric crystal pickups are now very widely used. Improvements in automatic record changers increased their use. The sale of records for 1938 was approximately twice that for 1937.

Single-ended tubes of both metal and glass construction (with grid terminals in the base) are now available in place of the previous grid-cap types and will probably influence future chassis design.

Circuit Trends

The most noticeable circuit trend was the increased use of negative feedback for improved audio-frequency quality. Combinations of negative and positive feedback for improved frequency characteristics without loss of gain were recognized.[13,14] Attention was directed to the use of feedback over as large a portion of the electroacoustical link between the detector and loud speaker as possible.[15] By this means, speaker and cabinet resonance and transients were minimized.

A tuned shielded loop housed within the receiver cabinet for signal pickup in the standard broadcast band was used to minimize local man-made electrical interference.[16]

A noise-reducing antenna utilizing a balancing principle was introduced.[17]

Use was made of a distortion limiter to reduce the harmonic content during high audio-frequency voltage swings. This system may be considered to be an audio-frequency automatic volume control.[18]

The use of direct current for the control of high-frequency inductance in tuning devices was reported.[19]

The search for noise-limiting circuits continued[20] although adequate relief from interference will require co-operative efforts of radio and electrical-appliance manufacturers. Various co-ordinating committees with representation from the groups involved were organized and gathered considerable data on the subject.[21–23] Methods of measuring radio interference have been improved.[24,25]

Methods of automatically controlling selectivity in the presence of interference were described.[26]

The detuning of amplifiers subject to automatic volume control has been corrected by providing a current feedback which introduces a quadrature compensating voltage in the input circuit, automatically neutralizing the change in tube capacitance with bias.[27] Similar means were reported to prevent change in transit-time input conductance with bias variations.[28]

The measurement of spurious responses resulting from external cross modulation originating in nonlinear circuits near the transmitter or the receiver received considerable attention. A survey of a typical situation as it exists in Seattle was made by the Radio Manufacturers Association.

The Standards Committee of the Radio Manufacturers Association reaffirmed the choice of 455 kilocycles as a standard intermediate frequency for superheterodynes in the United States. The result of previous co-operation between the Federal Communications Commission and the Radio Manufacturers Association in this matter was reported.[29]

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[10] Beverly Dudley, "Relays for tube circuits," *Electronics*, vol. 11, pp. 18–21; May, (1938).

[11] Herbert Chase, "Plastics for radio receivers," *Communications*, vol. 18, pp. 20, 21, 24; August, (1938).

[12] W. W. Broughton, "Die castings in radio applications," *R.M.A. Eng.*, vol. 3, pp. 25–35; November, (1938).

[13] L. I. Farren, "Some properties of negative feedback amplifiers," *Wireless Eng.*, vol. 15, p. 23–35; January, (1938).

[14] E. L. Ginzton, "Balanced feed-back amplifiers," Proc. I.R.E., vol. 26, pp. 1367–1379; November, (1938).

[15] H. S. Knowles, "Loud-speaker consideration in feed-back amplifiers." Presented, Rochester Fall Meeting, Rochester, N. Y., November 15, 1938.

[16] S. Goldman, "A shielded loop for noise reduction in broadcast reception," *Electronics*, vol. 11, pp. 20–22; October, (1938).

[17] V. D. Landon and J. Reid, "A new antenna system for noise reduction." Presented, I.R.E. Convention, New York, N. Y., June 16, 1938.

[18] M. L. Levy, "Distortion limiter for radio receivers," *Electronics*, vol. 11, pp. 26–27; March, (1938).

[19] "Magnetic tuning devices," *Wireless World*, vol. 42, p. 161; February 24, (1938).

[20] J. E. Dickert, "A new automatic noise limiter," *QST*, vol. 22, pp. 19–22; November, (1938).

[21] P. L. Bellaschi and C. V. Aggers, "Radio influence characteristics of electrical apparatus," *Elec. Eng.*, vol. 57, pp. 626–633; November, (1938).

[22] F. R. W. Strafford, "Interference from neon sign," *Wireless World*, p. 458; May 16, (1938).

[23] R. L. Haskins and C. W. Metcalf, "Real versus apparent station coverage," *Communications*, vol. 18, pp. 23, 24, 26; April, (1938).

[24] C. M. Burrill and E. T. Dickey, "The overvoltage timer and an example of its application to the measurement of radio interference," *R.M.A. Eng.*, vol. 3, pp. 16–21; November, (1938).

[25] C. J. Franks, "The measurement of radio noise interference," *R.M.A. Eng.*, vol. 3, pp. 7–10; November, (1938).

[26] J. F. Farrington, "Automatic selectivity control responsive to interference." Presented, I.R.E. Convention, New York, N. Y., June 16, 1938.

[27] R. L. Freeman, "Use of feedback to compensate for vacuum-tube input-capacitance variations with grid bias," Proc. I.R.E., vol. 26, pp. 1360–1366; November, (1938).

[28] M. J. O. Strutt and A. van der Ziel, "The causes for the increase of the admittances of modern high-frequency amplifier tubes on short waves," Proc. I.R.E., vol. 26, pp. 1011–1032; August, (1938).

[29] G. E. Gustafson, "The R.M.A. standard intermediate frequency," *R.M.A. Eng.*, vol. 3, p. 2; November, (1938).

There has been a growing interest in the subject of frequency modulation.[30] At least one company manufactured receivers for the reception of experimental frequency-modulated transmissions in certain ultra-high-frequency bands. The behavior of tuned circuits in the presence of frequency- and phase-modulated waves was analyzed.[31]

COMMUNICATION RECEIVERS

During the past year a number of improvements has been made in ship-to-shore radiotelephone circuits. A recently developed shore-station receiver designed for remotely attended operation eliminates the need of constant monitoring by a technical operator. The set has a new type of codan (carrier-operated device, antinoise) which employs crystal band-pass and band-elimination filters and is insensitive to noise operation. No adjustment is required to compensate for wide variations in noise level.[32] Several new ship equipments were made available, some having combined transmitters and receivers and others employing separate units. While the small units employ push-button control for switching between transmission and reception, the larger equipments have voice-controlled switching and also have selective ringing circuits in the receiver.[33]

Portable equipment for emergency use in bridging gaps in wire lines was developed also. This equipment uses the same voice-controlled transmitter employed in the ship equipment while the receiver used is similar to the shore-station receiver listed above. The effectiveness of the equipment was demonstrated following the hurricane in New England in September, 1938.

New police radio equipment operating in the 30- to 42-megacycle band was developed. The receivers have more stable oscillators and improved noise-suppression circuits. Several new types of vacuum-tube squelch circuits were devised to reduce the noise normally received during the carrier-off intervals.[34]

Short-wave single-side-band systems were developed for transoceanic service based on the transmission of a reduced carrier for pilot purposes and designed to obtain two transmission channels by separate utilization of each side band.[35,36]

The use of crystal-element filters in obtaining adjustable selectivity became general. There also was a noticeable trend towards the use of higher intermediate frequencies in receivers for operating at frequencies above four megacycles.

NAVIGATIONAL-AID RECEIVERS

Interest continued in utilizing ultra-high frequencies for aviation service. The United States Civil Aeronautics Authority installed a number of 75-megacycle marker-beacon transmitters and receivers for these transmissions were made available.[37,38] Experimental work continued on the development of ultra-high-frequency receivers for two-way communication, airport traffic control, radio-range systems, and instrument landing systems.[39–42]

Another important development is the radio altimeter for determining height above the ground rather than above sea level by measuring the time required for a frequency-modulated ultra-high-frequency radio signal originating in an airplane to reach the ground and be reflected back to the plane.[43,44]

A ground-station direction finder operating in the band from two to seven megacycles and capable of instantaneously and automatically giving a line of bearing on the transmission from an airplane was demonstrated.[45] An automatic direction finder for

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[30] C. B. Fisher, "Application of frequency modulation to radio transmission," *R.M.A. Eng.*, vol. 3, pp. 11–15; November, (1938).

[31] H. Roder, "Effects of tuned circuits upon a frequency-modulated signal," PROC. I.R.E., vol. 25, pp. 1617–1647; December, (1937).

[32] H. B. Fischer, "Remotely controlled receiver for radiotelephone systems." Presented, I.R.E. Convention, New York, N. Y., June 18, 1938.

[33] R. S. Bair, "Ship equipment for harbor and coastal radiotelephone service." Presented, I.R.E. Convention, New York, N. Y., June 18, 1938.

[34] "Police radio equipment," *Communications*, vol. 18, p. 38, October, (1938); *Pick-Ups*, pp. 6, 9; September, (1938).

[35] A. A. Oswald, "A short-wave single-side-band radiotelephone system," PROC. I.R.E., vol. 26, pp. 1431–1454; December, (1938).

[36] N. Koomans, "Single-side-band telephony applied to the radio link between the Netherlands and the Netherlands East Indies," PROC. I.R.E., vol. 26; pp. 182–206; February, (1938).

[37] H. I. Metz, "Report on the development of fan-type ultra-high-frequency radio markers as a traffic control letdown aid," Report No. 5, Department of Commerce, Bureau of Air Commerce, Safety and Planning Division, January, (1938).

[38] P. D. McKeel, J. M. Lee, and H. I. Metz, "The development of an improved ultra-high-frequency radio fan marker," Report No. 14, Department of Commerce, Bureau of Air Commerce, Safety and Planning Division, July, (1938).

[39] J. G. Hromada and P. D. McKeel, "The development of an airways ultra-high-frequency communication circuit," Report No. 6, Department of Commerce, Bureau of Air Commerce, Safety and Palnning Division, February, (1938).

[40] "Two-way communication," *Science*, vol. 88, supplement, p. 10; August 26, (1938).

[41] W. E. Jackson and J. G. Hromada, "Report on 125-mc airport traffic control tests at Indianapolis," Report No. 2, Department of Commerce, Bureau of Air Commerce, Safety and Planning Division, January, (1938).

[42] J. G. Hromada, "Preliminary report on a four-course ultra-high-frequency radio range," Report No. 3, Department of Commerce, Bureau of Air Commerce, Safety and Planning Division, January, (1938).

[43] "Radio Altimeter," *Communications*, vol. 18, p. 34; October, (1938).

[44] Sadahiro Matsuo, "A direct-reading radio-wave reflection-type absolute altimeter for aeronautics," PROC. I.R.E., vol. 26, pp. 848–858; July, (1938).

[45] "Aircraft direction finding," *Communications*, vol. 18, p. 33, October, (1938). *Science*, vol. 88, supplement, p. 10; September 16, (1938).

airplane use, designed to indicate continuously the bearing of a transmitter through 360 degrees, also was developed.[46]

MEASURING APPARATUS AND TECHNIQUES

The principle of inverse feedback exerted a considerable influence in measurement apparatus and technique. Its application to vacuum-tube voltmeters resulted in equipment of increased range and much improved stability.[47,48] The application of negative feedback to laboratory amplifiers also was described. This resulted in uniform standardized-gain amplifiers. Inverse feedback was used also in oscillators to reduce distortion.[49] Negative feedback was used to improve the selectivity of impedance bridges and to give selective circuits suitable for use as wave analyzers.[50]

Several entirely new circuit features are included in the design of an oscillator which does not generate harmonics and has exceptionally high frequency stability.[51]

There has been a general improvement in oscilloscopes in the direction of increased frequency range and over-all convenience of operation.[52] Several signal generators of improved performance and convenience appeared on the market.[48,53]

In the field of service equipment several new oscilloscopes were made available and inexpensive signal generators with frequency modulation for visual alignment also became generally accepted.[48]

New bridge circuits for the measurement of resistance, reactance, and the power factor of dielectrics were described.[54] Limit bridges for production testing in more convenient forms also appeared.[48]

With the increased interest in the measurement of external noise, new and improved noise meters appeared both in this country and abroad.[24,25,53]

Wave analyzers were made more convenient in operation and at the same time more selective by new crystal-filter applications.[55]

An audio-frequency curve tracer making the audio-frequency response characteristic directly visible was described.[56]

A new and revised edition of the Institute of Radio Engineers standards on receiver measurements was published in 1938.

STATISTICS ON BROADCAST RECEIVERS FOR THE UNITED STATES[57–60]

Average List Prices		
639 general models		$ 71.50
The average list price of all receivers sold reflects the large quantity of low-priced models and was approximately		35.00
360 table models		31.10
235 console and chairside models		127.50
Number of Models		
Total home receivers		899
Average number of tubes	6.45	
Consoles, including chairside and phonograph-radio combinations		331
Average number of tubes in 326 models	8.06	
Average size of loud speaker in 277 models	9.94 inches	
Average power output of 256 models	7.4 watts	
Table models		552
Average number of tubes in 547 models	5.36	
Average size of loud speaker in 370 models	5.84 inches	
Average power output of 333 models	2.36 watts	
Phonograph-radio combinations		126
Portable		16
Battery		90
Automobile		75
Remote control		30

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[46] "An automatic direction finder," *Communications*, vol. 18, pp. 10–11; October, (1938).

[47] F. M. Colebrook, "A valve-voltmeter with retroactive direct-voltage amplification, *Wireless Eng.*, vol. 15, pp. 138–142; March, (1938).

[48] "Laboratory and measuring equipments," *Communications*, vol. 18, pp. 17–19; August, (1938).

[49] F. E. Terman, R. R. Buss, W. R. Hewlett, and F. C. Cahill, "Some applications of negative feedback with particular reference to laboratory equipment." Presented, I.R.E. Convention New York, N. Y., June 16, 1938.

[50] H. H. Scott, "A new type of selective circuit and some applications," PROC. I.R.E., vol. 26, pp. 226–235; February, (1938).

[51] L. A. Meacham, "The bridge-stabilized oscillator," PROC. I.R.E., vol. 26, pp. 1278-1294; October, (1938).

[52] G. R. Mezger, "Oscillograph-design considerations." Presented, I.R.E. Convention, New York, N. Y., June 17, 1938. PROC. I.R.E., this issue, pp. 192-198.

[53] "The Physical Society's exhibition," *Wireless Eng.*, vol. 15, pp. 84–90; February, (1938).

[54] W. N. Tuttle, "Bridged-T and parallel-T null circuits." Presented, I.R.E. Convention, New York, N. Y., June 17, 1938.

[55] L. B. Arguimbau, "Application of quartz crystals to a wave analyzer." Presented, I.R.E. Convention, New York, N. Y., June 16, 1938.

[56] J. B. Sherman, "An audio-frequency-response curve tracer," PROC. I.R.E., vol. 26, pp. 700–712; June, (1938).

[57] *Radio Retailing*, "Set specifications, vol. 23, pp. 57–64; June, (1938).

[58] *Radio Retailing*, "Set specifications," vol. 23, pp. 29-32; July, (1938).

[59] *Radio Today*, "Sales features and specifications of the 1938–39 sets," vol. 4, pp. 16, 18–20, 26, 28, 32; July, (1938).

[60] *Radio Today*, "Features and specifications of the 1939 sets," vol. 4, pp. 20, 22, 44; August, (1938).

Manufacturing Quantities	
Receivers (approximately)	6,000,000
Vacuum tubes	70,000,000
New receiving types announced	63

Note: Speaker size and power output data do not include farm radios. Mechanical tuning was included in approximately 40 per cent of the receivers. Automobile receiver data are not included in the number of sets, price averages, or in the average number of tubes.

This report was prepared under the supervision of the Annual Review Committee by the Technical Committee on Radio Receivers of the Institute of Radio Engineers, the personnel of which follows.

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PART IV—TELEVISION AND FACSIMILE*

The report on television is divided into sections on transmitters, receivers, and systems, while the subject of facsimile is treated in two parts, broadcasting and point-to-point services.

Television

TRANSMITTERS

Circuits

Considerable improvement has been made in television transmitters during the year. In the United States the modulating frequency range of transmitters was extended to utilize most of the available six-megacycle band. Negative modulation and direct transmission of the direct-current component were generally adopted.

Networks suitable for carrier-frequency operation at both high and low power were applied in the transmitter to obtain the proper transmission characteristic for partially suppressing one side band. Field tests and measurements showed this method of operation to be feasible.

Steady progress was made in the electrical and mechanical design of pickup equipment for studio use. The video-frequency band width was increased to approximately six megacycles and the circuits made more stable. The camera preamplifier and coupling circuits were improved and the signal-to-noise ratio increased.

The British Broadcasting Corporation now uses mechanical equipment for timing synchronizing pulses at the Alexandra Palace transmitter.

In Germany, projection of a continuously moving standard motion-picture film onto a dissector or scanning disk was reported. The transformation from standard film speed to television field-repetition rate was accomplished by stationary displaced optical elements and a rotating shutter.[1]

A new continuous-type motion-picture-film scanner was developed in the United States.[2]

The Eiffel Tower transmitter at Paris was reported to be operated at a peak power of 30 kilowatts.

Antennas

Improvements were made in transmitting antennas affecting both mechanical design and electrical characteristics. Antennas suitable for installation on the small space available on top of tall buildings were designed. The directivity pattern was improved for horizontally polarized antennas so that they have a circular pattern in the horizontal plane and directivity toward the horizon in the vertical plane, resulting in a substantial power gain. Improved antenna designs give uniform impedance over more than one six-megacycle television channel.

Comparisons of polarization of the radiated wave were made indicating that a better signal-to-ignition interference ratio and less multipath interference is obtained with horizontal than vertical polarization.[3]

RECEIVERS

Circuits and Antenna Systems

About 60 different models of television sets are on the English market at this time[4] including several home projection receivers and one mechanical receiver.[5] Theater projection equipments, both electronic and mechanical, for pictures six feet by eight feet were demonstrated.[6]

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* Decimal classification: R583.

[1] K. Thom, "Neuer mechanischer filmabtaster," *Zeit. der Fernseh. A. G.*, vol. 1, pp. 24–28; August, (1938).

[2] H. S. Banford, "A non-intermittent projector for television film transmission," *Jour. Soc. Mot. Pic. Eng.*, vol. 31, pp. 453–461; November, (1938).

[3] R. W. George, "Study of ultra-high-frequency wide-band propagation characteristics." Presented, I.R.E. Convention, New York, N. Y., June 18, 1938, PROC. I.R.E., vol. 27, pp. 28–35; January, 1939.

[4] "Teleolympia," *Telev. and Short-Wave World*, pp. 521–552; September, (1938).

[5] "The Scophony home receiver," *Telev. and Short-Wave World*, pp. 724–725; December, (1938).

[6] "The Baird big-screen theatre receiver," *Telev. and Short-Wave World*, pp. 459–460; August, (1938).

In keeping with the commercial trends in sound broadcast receivers in the United States, the design of television receivers has seen the introduction of pretuned station selection.[7] Several companies have begun the design of a line of receivers for the market in 1939,[8] when scheduled programs will be transmitted, while some receivers and kits[9] appeared on the market. Designs for home-constructed receivers were published.[10–13] The introduction of tubes with high mutual conductance permitted improvements in the design of receivers.

Progress was made in circuits and cathode-ray tubes for producing large pictures both by increasing tube size and by projection.[14–21] Experimental apparatus incorporating these improvements was demonstrated to large groups.[22]

Considerable work was done in Germany on large projection and directional screens.[23] Experiments were continued with color television.[24,25]

Improvements were made in receiving antennas in the matters of directivity, selectivity, and effective height.[26]

SYSTEM ASPECTS[27]

Theory

A mathematical analysis of the vestigial-side-band system of image transmission[28] was made. Studies in phase and amplitude distortion[29] and in synchronizing wave forms[30] were reported.

A description of a proposed television system employing more than twofold interlacing was given.[31] In this system it is proposed to transmit the scanning wave shapes on subcarriers. Reduction of necessary band width without loss of detail and without increase of interline flicker is claimed.

Standards

The International Radio Conference at Cairo revised the classification of radio emissions[32] so as to designate waves employed in facsimile transmission as Type A4 and those employed in television as Type A5 waves. The United States Federal Communications Commission revised its Rules and Regulations to conform with this action.

Fourteen television transmission standards were formulated by the Radio Manufacturers Association and submitted to the Federal Communications Commission. Several transmitters were operated in accordance with these standards.[33–35]

British transmission standards remain unchanged.[36] New German transmission standards were adopted.[37–41] In Berlin a new transmitter operating on the new standards was placed under test.

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[7] H. T. Lyman, "Television r-f input circuits," *R.M.A. Eng.* vol. 3, pp. 3–6; November, (1938).

[8] *Radio Weekly*, vol. 46, no. 17, p. 3; October, (1938).

[9] *Radio Retailing*, vol. 23, no. 9, p. 36; September, (1938).

[10] D. G. Fink, "A laboratory television receiver," *Electronics*, vol. 11. In 6 parts, July–December, (1938).

[11] M. P. Wilder, "The construction of television receivers," *QST*, vol. 22, pp. 23–27; April, (1938); pp. 39–41, 96, 98; May, (1938).

[12] J. B. Sherman, "Building television receivers with standard cathode-ray tubes," *QST*, vol. 22, pp. 21–25; October, (1938).

[13] C. C. Shumard, "A practical television receiver for the amateur," *QST*, vol. 22, pp. 21–25, 72, 74, 76; December, (1938).

[14] H. A. Wheeler, "Wide-band amplifiers for television." Presented, I.R.E. Convention, New York, N. Y., June 18, 1938. Summary, PROC. I.R.E., vol. 26, p. 676; June, 1938.

[15] E. W. Engstrom and R. S. Holmes, "Television receivers," *Electronics*, vol. 11, p. 28–31, 63–66; April, (1938).

[16] F. Alton Everest, "Amplification problems in television," *Communications*, vol. 18, pp. 15–19, 38; January, (1938).

[17] F. Alton Everest, "Wide-band television amplifiers," *Electronics*, vol. 11, pp. 16–19; January, (1938).

[18] F. Alton Everest, "Wide-band television amplifiers—II," *Electronics*, vol. 11, pp. 24–27; May, (1938).

[19] Albert Preisman, "Some notes on video-amplifier design," *RCA Rev.*, vol. 2, pp. 421–432; April, (1938).

[20] E. W. Engstrom and R. S. Holmes, "Television i-f amplifiers," *Electronics*, vol. 11, pp. 20–23; June, (1938).

[21] E. W. Engstrom and R. S. Holmes, "Television v-f circuits," *Electronics*, vol. 11, pp. 18–21; August, (1938).

[22] S. W. Seeley and D. E. Foster, "Principles and methods in television laboratory technique." Presented, Rochester Fall Meeting, Rochester, N. Y., November 16, 1938. Summary, *Electronics*, vol. 11, p. 11; December, (1938).

[23] E. H. Traub, "Television at the Berlin radio exhibition 1938," *Telev. and Short-Wave World*, pp. 542–544; September, (1938), and continued in October, (1938), issue.

[24] H. Pressler, "Fernsehen in natürlichen Farben," *Tel. Fern. und Funk-Tech.*, vol. 27, pp. 137–141; April, (1938).

[25] M. von Ardenne and H. Pressler, "Zum problem des farbfernsehens," *Tel. Fern. und Funk-Tech.*, vol. 27, pp. 264–273; July, (1938).

[26] S. W. Seeley, "Effect of the receiving antenna on television reception fidelity," *RCA Rev.*, vol. 2, pp. 433–441; April, (1938).

[27] A general survey of television development status in engineering and economic aspects was published in the magazine *Business Week* for December 31, 1938.

[28] S. Goldman, "Television details and selective side-band transmission," presented before Rochester Fall Meeting, Rochester, N. Y., November 15, 1938. Summary, *Electronics*, vol. 11 p. 10; December, 1938.

[29] H. A. Wheeler, "Interpretation of amplitude and phase distortion in terms of paired echoes." Presented, Rochester Fall Meeting, Rochester, N. Y., November 15, 1938.

[30] F. J. Bingley, "The problem of synchronization in cathode-ray television," PROC. I.R.E., vol. 26, pp. 1327–1339; November, (1938).

[31] "Television without sync signals," *Electronics*, vol. 11, pp. 33–34, 68; March, (1938).

[32] Article 5, Section 1, General Radio Regulations, Cairo, 1938.

[33] Albert F. Murray, "R.M.A. complete television standards," *Electronics*, vol. 11, pp. 28–29, 55; July, (1938).

[34] Albert F. Murray, "The R.M.A. television synchronizing standard—a semi-technical explanation," *R.M.A. Eng.*, vol. 3, pp. 22–24; November, (1938).

[35] Albert F. Murray, "Television standards," *Communications*, vol. 18, pp. 14–16, 28, 33; December, (1938).

[36] Brown, Blumlein, Davis, and Green, "The Marconi-E.M.I. television system," *Jour. I.E.E.* (London), December, (1938).

[37] F. Banneitz, "Die neue Norm des Deutschen Fernsehrundfunks," *Fernsehen und Tonfilm*, pp. 53–54; July, (1937).

[38] F. Banneitz, "Die neue Fernsehnorm der Deutschen Reichspost," *Fernsehen und Tonfilm*, pp. 85–86; November, (1937).

[39] F. Banneitz, "Normung der Gleichlaufzeichen des Deutschen Fernsehrundfunks," *Tel. Fern. und Funk.*, vol. 27, p. 157; May, (1938).

[40] F. Banneitz, "Zur normung des Deutschen Fernsehrundfunks," *Fernsehen und Tonfilm*, p. 27; April, (1938).

[41] D. V. Oettingen, R. Urtel, and G. Weiss, "Ueber die Einkanalsynchronisierung im Fernsehen," *Tel. Fern. und Funk-Tech.*, vol. 27, pp. 158–166; May, (1938).

No definite standards have been adopted as yet in France.[42]

Field Tests and Operation

Measurements of the field strength of the London television transmitter were made[43] in a northerly direction up to 500 miles and appear to establish quite clearly the existence of a weak sky wave at distances beyond about 90 miles under both day and night conditions.

Television field tests under conditions approximating those which would obtain in a public service were continued in the United States. Periods of regular program transmission have alternated with periods of suspension in order that equipment changes might be made. These tests were utilized to study the problems of technical operation and program production and in addition to prove the new transmission standards.

Mobile pickup equipment including a 177-megacycle relay transmitter mounted in trucks was put in experimental service and performed satisfactorily.[44] Location pickups were successfully accomplished over distances up to twenty-seven miles.

Frequencies of the order of 150 megacycles were successfully employed for propagation of television signals between two points, such as a mobile pickup unit and a central distributing station.[44]

Interference problems as bearing upon the sense of polarization of ultra-high frequencies and the minimization of multipath effects by antenna design also received attention.[26,45]

In England, experiments were conducted on the transmission of visual signals over two or three miles of selected telephone lines. Thus, many important sources of near-by program material may be linked to the balanced-pair television cable encircling central London.

The coaxial television cable between Berlin and Leipzig was extended.

Experiments have shown that a wide-band signal of the type required for television can be satisfactorily transmitted over the New York-Philadelphia coaxial system.[46]

Facsimile

BROADCAST FACSIMILE

In the United States unprecedented activity was noted in the field of experimental facsimile transmission over regular broadcast channels. Seventeen stations in ten cities installed facsimile scanners and began collecting test data preparatory to the daily transmission of material of public interest. A few transmission schedules were carried out on ultra-high frequencies, using several bands assigned for this purpose in the range from twenty-four to forty-seven megacycles. Toward the close of the year, a few stations announced regular schedules.

Two stations in California tested the extent to which power-line network synchronization is possible over extended areas, and have proved its practicability by operating two transmitters over a 170-mile wire line from a single scanner.

Continuous-feed recorders employing rolls of paper as contrasted with single sheets became accepted practice although no single printing method was adopted as a standard.

Most of the development program was toward the simplification of receiving equipment. A system using reciprocating scanning was used in many instances because of its inherent simplicity. This system was adapted to recording on dry electrosensitive paper. The trend was toward a dry paper with a black marking on a white background. Manufacturing facilities were organized for the quantity production of facsimile attachments for regular receiving equipment. Availability of these machines for experimental use was announced to the public. Phonograph records of facsimile signals useful for testing recorders were produced.

Some systems employ continuous scanning, with no unused time between active scanning lines. Among these is the rotating-helix-drum system using carbon-paper recording,[47] arranged to give both black-and-white reception and half tones. A number of special features is incorporated in this system, such as compensation to improve half-tone characteristics, a voltage regulator for stability, and a timer with audible and visual signals to insure regular paging of the received copy. These receivers are complete in one cabinet: a fixed-tuned receiver, the facsimile recorder, and the time switch. Synchronization is primarily by reference to a common power network but attachments are available for use in areas outside of that covered by a single power system.

Other continuous-scanning systems were devel-

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[42] "The world's most powerful television station," *Telev. and Short-Wave World*, pp. 261–264, May, (1938).

[43] T. C. MacNamara and D. C. Birkinshaw, "The London television service," *Jour. I.E.E.* (London), December, (1938).

[44] John Evans, C. H. Vose, and H. P. See, "RCA-NBC television mobile units." Presented, I.R.E. Convention, New York, N. Y., June 18, 1938. Summary, PROC. I.R.E., vol. 26, p. 664; June, (1938).

[45] Gill and Whitehead, "Electrical interference with radio reception," *Jour. I.E.E.* (London), vol. 83, pp. 345–394; September, (1938).

[46] M. E. Strieby, "Television over the coaxial cable," *Bell Lab. Rec.*, vol. 16, pp. 188–195; February, (1938).

[47] Charles J. Young, "Equipment and methods developed for broadcast facsimile service," *RCA Rev.*, vol. 2, pp. 379–395; April, (1938).

oped wherein several styluses move consecutively in a single direction over dry electrosensitive paper, slowly advanced from a roll.

Standards were discussed by various standards committees, but to date are not complete. It is believed possible that standards can be adopted which will permit operation of several different types of machines on a common signal.

Definition based on 100 and 125 lines per inch was obtained. Paper speeds varying from 0.6 to 1.5 inches per minute and width of copy varying from 4 to 7.5 inches were employed.

POINT-TO-POINT FACSIMILE

Message Facsimile

A new type of facsimile machine designed particularly for handling telegrams between customers' offices and the central telegraph office was put in service. About the size of a teleprinter, it serves both as a transmitter and recorder, using a dry light-gray paper for recording. An automatic concentrator at the central office permits a few central-office machines to serve a large number of customers.

Telepicture

Wire

Two basic types of picture-transmission service are employed by newspicture-distributing organizations within the United States depending on the type of wire-line plant utilized. One type employs a specially engineered private-line network connecting up fixed points; the other utilizes regular long-distance message toll circuits. Progress has been made in refinement of the terminal apparatus originally designed for the fixed-network service. Organizations using message toll circuits continued development programs planned specifically for this type of service. Improvements in apparatus design resulted in a worthwhile improvement in the printed copy.

The trend in portable-equipment design for use primarily on toll circuits was to combine the transmitter and receiver and to include tuning-fork synchronization.

Some attempts were made by organizations employing message toll circuits to standardize machine design and operating practice.

Radio

A steady increase in international traffic was noted since the inauguration of long-distance point-to-point service. During 1938 the increase at the New York terminal was approximately 30 per cent over the 1937 totals. Similar increases were noted abroad.

Miscellaneous operating improvements, application of solar radiation and earth-magnetic data in the selection of suitable frequencies and keying speeds, education of customer and operating staffs in their respective handling problems, were jointly responsible for a noticeable improvement in copy reaching the public or private user. Private companies and foreign administrations sponsoring the established service continued their active investigation of propagation methods best suited to long-distance service. Time-modulation propagation methods make commercial copy generally possible but at the expense of reduced handling speed. General improvement of radio station apparatus and a clearer understanding of the propagation medium are pointing the way to further progress.[48]

The adaptation of facsimile facilities to mobile uses received much attention during the year. Facsimile copy was successfully transmitted to and from aircraft, ships, and automobiles.

This report was prepared under the supervision of the Annual Review Committee by the Technical Committee on Television and Facsimile of the Institute of Radio Engineers, the personnel of which follows.

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[48] E. Hudec, "The transmission of pictures according to the impulse method," *Tel. Fern. und Funk-Tech.*, vol. 1, (1938).

PART V—TRANSMITTERS AND ANTENNAS*

Transmitters for broadcasting, point-to-point, and marine use are treated and include both low- and high-power units. Frequency stability, modulation methods, and schemes for conserving space in the frequency spectrum are mentioned. Antenna developments are chiefly in the field of vertical directivity.

TRANSMITTERS

Improvements in the circuit design of broadcast transmitters centered principally upon increasing power efficiency. Several schemes directed toward

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* Decimal classification: R 350×R 320.

this end were proposed.[1-3] Although high power efficiency is usually considered important chiefly from the standpoint of power cost, and of major significance only in very high-power transmitters, it has been found that high-efficiency circuits may influence design for other reasons. For instance, the cooling system may be substantially simplified by reduced requirements for heat dissipation. Also, the use of radiation-cooled tubes in medium-power transmitters is more practical with a high-efficiency circuit. The influence of such considerations is evident in the commercial transmitters of the year.

Modern styling continues to be a feature of all lines of broadcast transmitters and associated apparatus.

The importance of frequency stability in radio transmitters lends interest to the development of an oscillator[4] whose frequency variations are only a very small fraction of current frequency tolerances.

A method has been presented together with experimental evidence whereby the ideal of a carrier and single-side-band system may be approached in the broadcast field without immediate alteration of the millions of receivers now in use.[5] In this method only the outer part of one side band is cut away in the higher-frequency region where modulation depth is low, while retaining both side-band components in full for the lower frequencies where modulation is large.

Considerable activity was shown in the field of frequency and phase modulation[6,7] as contrasted to amplitude modulation and several frequency-modulated transmitters began experimental broadcasting on ultra-high frequencies.

The progress reports on television and facsimile cover in detail the developments in those fields, but a few notes on transmitters for these applications are given here. A number of transmitters with power outputs as high as 40 kilowatts were developed and made available commercially. A method of modulation particularly applicable to television systems, wherein a quarter-wavelength line is used in conjunction with an absorbing vacuum tube and is connected at a favorable point in the output circuit of the equipment, was described.[8] It is claimed that the system permits wide-band modulation since a minimum of selective circuits is involved between its point of connection and the radiator.

In point-to-point equipment considerable interest was shown in single-side-band transmission or variations thereof. Commercial transoceanic service was inaugurated using short-wave apparatus and a system of transmitting one side band and a reduced carrier or pilot frequency. The other side band may be utilized for twin-channel operation.[9,10]

Contrasting with the success obtained with single-side-band or selective-side-band transmission for telephone service, extensive analysis and tests of this method for high-speed telegraph and facsimile services failed to show corresponding advantages over double-side-band transmission.[11] Because of the use of threshold limiting in receivers to reduce or eliminate the effects of fading and background, unsymmetrical signal wave shapes produced by the adverse phase characteristics of the selective side-band method can result in reproduced records that are entirely different from those originally scanned. The requirements for facsimile transmission are more rigid in respect to phase and frequency distortion than are those for speech or music.

In the marine telegraph field, new transmitters satisfying the Federal Communications Commission's requirements[12] for safety of life at sea became available and a considerable number of installations made. These transmitters are characterized by improved frequency stability and high percentage modulation on interrupted-continuous-wave operation.

Additional facilities were provided for coastal and harbor radiotelephone communication. A wide variety of transmitters varying in power from 5 to 75 watts were developed for use aboard ship. In general the transmitter, receiver, and control equipment are included in a single unit with both transmitter and receiver having crystal control. The higher-powered equipments offer as useful adjuncts selective signal-

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[1] F. E. Terman and J. R. Woodyard, "A high-efficiency grid-modulated amplifier," PROC. I.R.E., vol. 26, pp. 929–945; August, (1938).

[2] R. B. Dome, "High-efficiency modulation systems," PROC. I.R.E., vol. 26, pp. 963–982; August, (1938).

[3] N. F. Gaudernack, "A phase-opposition system of amplitude modulation," PROC. I.R.E., vol. 26, pp. 983–1008; August, (1938).

[4] L. A. Meacham, "The bridge-stabilized oscillator," PROC. I.R.E., vol. 26, pp. 1278–1294; October, (1938).

[5] P. P. Eckersley, "Asymmetric-side-band broadcasting," PROC. I.R.E., vol. 26, pp. 1041–1092; September, (1938).

[6] D. L. Jaffe, "Armstrong's frequency modulator," PROC. I.R.E., vol. 26, pp. 475–481; April, (1938).

[7] C. B. Fisher, "Frequency modulation." Presented, Rochester Fall Meeting, Rochester, N. Y., November 14, 1938. *R.M.A. Eng.*, vol. 3, pp. 11–15; November, (1938).

[8] W. N. Parker, "A unique method of modulation for high-fidelity television transmitters," PROC. I.R.E., vol. 26, pp. 946–962; August, (1938).

[9] N. Koomans, "Single-side-band telephony applied to the radio link between the Netherlands and the Netherlands East Indies," PROC. I.R.E., vol. 26, pp. 182–206; February, (1938).

[10] A. A. Oswald, "A short-wave single-side-band radiotelephone system," PROC. I.R.E., vol. 26, pp. 1431–1454; December, (1938).

[11] J. E. Smith, B. Trevor, and P. S. Carter, "Selective side-band vs. double side-band transmission of telegraph and facsimile signals," *RCA Rev.*, vol. 3, pp. 213–238; October, (1938).

[12] Federal Communications Commission, "Ship Radiotelegraph Safety Rules," May 21, 1937, mimeograph 21,442.

ing systems, voice-operated carrier control, and other refinements.

At the shore end of the coastal and harbor radiotelephone systems, unattended transmitter and receiver installations were made with the control unit placed in the telephone central-office building.[13,14]

ANTENNAS

In the broadcast frequency range, the use of concentric arrays of short antennas to provide control over vertical directivity was investigated with interesting results.[15] Arrays of this kind have been shown to provide a somewhat greater gain than can be obtained from a single vertical half-wave antenna and, by arrangement of the concentric groups, it becomes possible to control the radiation pattern for either ground-wave or combined ground-wave and sky-wave radiation as desired.

A novel array was installed at KDKA wherein the small high-angle lobe radiated from a three-quarter-wave vertical antenna is suppressed by a similar but opposite-phase radiation from a surrounding ring of eight short suppressor antennas. The net result is that only the strong low-angle lobe from the control radiation is effective.[16]

The increased use of multiple-element antenna systems has occasioned the development of instruments for monitoring the current amplitude and phase relationships in the elements, since it is these relationships which control the directional characteristics of an array.[17] Such instruments are now in commercial use. These instruments also save considerable time and labor during the initial adjustments of an array. A sample of the current in each element is obtained by placing a coil, generally a single turn, in proximity to each element. The energy induced in the coil from the element is transmitted to the monitoring instrument over a small coaxial transmission line.

Equipment for controlling the amplitude and phase of the currents distributed to the elements of an array was also developed. These equipments permit control of the element-current relationships under power to compensate for changes in antenna and circuit-element characteristics.

The popularity of the shunt-excited antenna was enhanced by the development of a coupling system which eliminates the need for all apparatus at the antenna base except the transmission-line current meter.[18] The system utilizes the distributed constants of parallel wires to accomplish this purpose.

A number of theoretical papers appeared in the literature furthering the knowledge of the performance of various antennas.[19,20]

In the ultra-high-frequency field, considerable work was done on antennas for application to television to obtain uniform impedance characteristics over a wide range of video frequencies. Considerable work was also done on investigating antennas for use in aircraft navigation.[21–24] Further work was done on the multiple-unit steerable antenna reported last year[25] and a system consisting of sixteen rhombic antennas in a line two miles long and connected to a receiver by buried coaxial transmission lines was erected.

A valuable contribution to the knowledge of ship-antenna performance was made available through the Federal Communications Commission.[26] Data were secured during the year by a survey made of somewhat over one hundred American vessels. The data include resistance, equivalent capacitance, natural frequency, resistance at the natural frequency, effective height, radiation efficiency, radiated power, and field intensity at one nautical mile with a specified input.

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[13] C. N. Anderson and H. M. Pruden, "Radiotelephone system for harbor and coastal service." Presented, I.R.E. Convention of the I.R.E., New York, N. Y., June 18, 1938.

[14] W. M. Swingle and Austin Bailey, "Coastal and harbor ship radiotelephone service from Norfolk, Virginia." Presented, I.R.E. Convention, New York, N. Y., June 18, 1938.

[15] W. W. Hansen and J. R. Woodyard, "A new principle in directional antenna design," PROC. I.R.E., vol. 26, pp. 333–345; March, (1938).

[16] R. N. Harmon, "KDKA low-angle antenna array." Presented, I.R.E. Convention, New York, N. Y. June 16, 1938.

[17] J. F. Morrison, "Simple method for observing current amplitude and phase relations in antenna arrays," PROC. I.R.E., vol. 25, pp. 1310–1326; October, (1937).

[18] W. H. Doherty and O. W. Towner, "A 50-kilowatt broadcast station utilizing the Doherty amplifier and designed for expansion to 500 kilowatts." Presented, I.R.E. Convention, New York, N. Y., June 16, 1938.

[19] L. V. King, "On the radiation field of a perfectly conducting plane earth, and the calculation of radiation resistance and reactance," *Phil. Trans. Roy. Soc.* (London), vol. 236, pp. 381–422; November 2, (1937).

[20] L. Page and N. I. Adams, Jr., "Electrical oscillations of a probate spheroid," *Phys. Rev.*, vol. 53, pp. 819–831; May 15, (1938).

[21] H. Diamond and F. W. Dunmore, "Experiments with underground ultra-high-frequency antenna for airplane landing beam," PROC. I.R.E., vol. 25, pp. 1542–1560; December, (1937).

[22] G. L. Haller, "Constants of fixed antennas on aircraft," PROC. I.R.E., vol. 26, pp. 415–420; April, (1938).

[23] S. Matsuo, "A direct-reading radio-wave-reflection-type absolute altimeter for aeronautics," PROC. I.R.E., vol. 26, pp. 848–858; July, (1938).

[24] E. Kramar and W. Hahnemann, "The ultra-short-wave guide-ray beacon and its application," PROC. I.R.E., vol. 26, pp. 17–44; January, (1938).

[25] H. T. Friis and C. B. Feldman, "A multiple unit steerable antenna for short-wave reception," PROC. I.R.E., vol. 25, pp. 841–917; July, (1937).

[26] Statements of K. A. Norton, R. Bateman, and C. A. Ellert before the Federal Communications Commission Hearing, November 14, 1938; Federal Communications Commission, mimeograph 30,539.

Standards on transmitters and antennas were issued by the Institute of Radio Engineers.

This report was prepared under the supervision of the Annual Review Committee by the Technical Committee on Transmitters and Antennas of the Institute of Radio Engineers, the personnel of which follows.

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PART VI—WAVE PROPAGATION*

By dividing the radio spectrum into several frequency bands, the presentation of developments in this field has been clarified.

GENERAL

Notable progress was made in understanding the processes of radio wave propagation and in applying such knowledge to practical use.

A special instance of the latter is the London Report[1] prepared at the end of 1937 by a special group for the use of the Cairo Radio Conference. That report summarized existing data particularly in respect to average received field intensities for various times and conditions, throughout the spectrum of radio frequencies above 150 kilocycles. It also gave data on maximum usable frequencies and skip distances for long-distance transmission. Its major omissions were data on frequencies below 150 kilocycles and on noise field intensities.

Knowledge of the facts of radio wave propagation has been expanding so rapidly in the last few years, and the valuable literature now available is so extensive, that few engineers have been able to keep even partially informed. Such information is necessary for wise choice of frequencies for any kind of radio transmission. In this connection the London Report renders a direct service to radio engineers.

During 1938, accurate calculation of ground-wave field intensities became possible through formulas developed independently by two different methods. One[2–4] of the methods is based on an exact solution of the Maxwell equations with proper boundary conditions, and the other[5] on the phase-integral method. The results of the two agree closely. Both methods take account of the effects of ground conductivity and dielectric constant upon diffraction around the spherical earth, and one also gives the effect of refraction caused by the small monotonic decrease in the dielectric constant of the atmosphere with increase in height. They permit calculation for vertical antennas of any height, elevated above as well as located on the ground. A number of other publications[6–10] appeared, adding to the knowledge of ground-wave propagation.

December 5, 1938, was the seventieth birthday of Professor A. Sommerfeld, whose classic paper in 1909 applying mathematical physics to radio wave propagation laid the foundation for subsequent progress in the calculation of ground-wave field intensities. He first applied the Lorentz reciprocity theorem to calculating antenna radiation and reception.

The progress in understanding the processes of radio wave transmission was characterized this year by more exact knowledge of the rôle played by the ionosphere in all long-distance transmission, and of the effects of troposphere discontinuities in wave refraction at high and particularly at ultra-high frequencies. A basis for prediction of radio transmission conditions was laid by the monthly publication of ionosphere data summaries in the PROCEEDINGS.

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* Decimal classification: R113.7.

[1] "Report of the Committee on Radio Wave Propagation," PROC. I.R.E., vol. 26, pp. 1193–1234; October, (1938).

[2] B. van der Pol and H. Bremmer, "The diffraction of electromagnetic waves from an electrical point source round a finitely conducting sphere, with applications to radio-telegraphy and the theory of the rainbow," Part I, *Phil. Mag.*, vol. 24, pp. 141–176; July, (1937); Part II, vol. 24, pp. 826–864; November, (1937).

[3] B. van der Pol and H. Bremmer, "The propagation of radio waves over a finitely conducting spherical earth," *Phil. Mag.*, vol. 25, pp. 817–834; June, (1938).

[4] B. van der Pol and H. Bremmer, "Results of a theory of the propagation of electromagnetic waves over a sphere of finite conductivity," *Hochfrequenz. und Elecktroakustik*, vol. 51, pp. 181–188; June, (1938).

[5] T. L. Eckersley and G. Millington, "Application of the phase integral method to the analysis of the diffraction and refraction of wireless waves round the earth," *Phil. Trans. Roy. Soc.*, vol. 237, pp. 273–309; June 10, (1938).

[6] K. F. Niessen, "On the field of a vertical half-wave aerial at any height above a plane earth," *Ann. der Phys.*, vol. 31, pp. 522–530; March, (1938).

[7] K. F. Niessen, "Ground absorption for horizontal dipole aerials," *Ann. der Phys.*, vol. 32, pp. 444–458; July, (1938).

[8] P. Rhasin, "On the electromagnetic field from a vertical half-wave aerial above a plane earth," *Tech. Phys. of U.S.S.R.*, vol. 5, pp. 29–30 (in English).

[9] G. Latmiral, "Surface radiation from horizontal aerials and measurements of electrical constants of the ground," *Alta Freq.*, vol. 7, pp. 509–535; August–September, (1938).

[10] J. S. McPetrie, "Reflection coefficient of the earth's surface for radio waves," *Jour. I.E.E.* (London), vol. 82, pp. 214–218; February, (1938).

Means for the closer estimation of the effects on radio transmission of certain ionosphere irregularities were provided by the preparation and prompt dissemination of magnetic character figures for every half day.

MEDIUM FREQUENCIES (150–1500 KILOCYCLES)

At a hearing held in the United States by the Federal Communications Commission on power requirements of ship radio stations, evidence was presented that for propagation over sea water at or near 500 kilocycles fading at night begins at a distance of 330 to 480 kilometers, depending principally upon the latitude of the sky-wave transmission path. It was shown that sky-wave transmission is dependent upon the latitude of the transmission path, being more intense at low latitudes. Also, data were given on the intensities of atmospheric noise ("static") as received at sea on voyages across the north Atlantic, through the Gulf of Mexico, and through the Panama Canal to Honolulu. The atmospheric noise was more than 20 times as strong in the latitude range 10 degrees to 15 degrees north as in the range 50 degrees to 55 degrees north; the received atmospheric noise was two to four times as strong at night as during the day; the ratio between peak and average atmospheric noise was usually larger during the daytime. It was found that the data could be explained by the assumption that the atmospheric noise originated in thunderstorms within a radius of about 1000 miles from the observer, being propagated from the thunderstorm sources by ground waves during the day and night at short distances and by sky waves at night over the longer distances. The higher atmospheric noise at night is a result of greater distance range of propagation of any radio waves at night.

A co-operative measurement program in several countries during winter nights indicated that long-distance broadcast transmission between the United States and Europe gives very much lower fields, and is more variable from day to day, than transmission between South America and either the United States or Europe. This appears to be due to propinquity of the transmission path to the north magnetic pole. These measurements and others showed that field intensities of sky waves at broadcast frequencies have decreased from year to year as sunspot numbers increased. For example, average fields during the spring of 1938 were 1/3 to 1/10 as great as during the spring of 1935.

A comparison of broadcast transmission at about 600 and 1500 kilocycles showed that 600-kilocycle intensities reach their full night values three or four hours after sunset, while 1500-kilocycle intensities rise to their full night values within about one hour after sunset.

The study of wave propagation at broadcast frequencies was advanced by work upon methods of measurement of field intensity. This included proposals for standardization by the Federal Communications Commission of procedures for determining broadcast coverage by field intensity surveys in the coverage area, and for interpreting such survey data in terms of station performance. There is a need for extension of efforts along this line, particularly clarification of the methods and data for stations having directional antennas.

There was progress in the commercial development of technique and equipment for field intensity measurement.[11–13] A critical study[14] of typical commercial field-intensity-measuring equipment showed that the errors of measurement at broadcast frequencies may be as much as 20 per cent. Eight such errors were analyzed and the amounts of their effects determined. By the application of suitable correction factors determined in the laboratory and by careful installation, the accuracy of measurement may be made better than within 5 per cent. A theoretical factor for taking into account the effect of the distributed capacitance of the loop antenna was verified experimentally. Several methods of measurement were devised for reducing this error to negligible order; good ones are the use of a shielded loop antenna with the calibrating voltage inserted at one end, and the use of a balanced loop antenna with an auxiliary fine-tuning condenser for measuring the antenna voltage step-up by the condenser-variation method.

HIGH FREQUENCIES (1500 to 30,000 KILOCYCLES)

The major facts of wave propagation in this frequency range are determined by the ionosphere. Knowledge of the ionosphere and its application to radio transmission were notably advanced in 1938. Comprehensive data on the daily, seasonal, and other changes of virtual height and critical frequencies of the ionosphere layers were published[15] monthly in the

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[11] W. A. Fitch and W. S. Duttera, "Measurement of broadcast coverage and antenna performance," *RCA Rev.*, vol. 2, pp. 396–413; April, (1938).

[12] W. A. Fitch, "Further developments in the design and technique of operation of field intensity-measuring equipment." Presented, I.R.E. Convention, New York, N. Y., June 17, 1938. Summary, PROC. I.R.E., vol. 26, p. 665; June, (1938).

[13] J. V. Cosman, "Portable field intensity meter," *Communications*, vol. 18, pp. 22–23; September, (1938).

[14] H. Diamond, K. A. Norton, and E. G. Lapham, "On the accuracy of radio field-intensity measurement at broadcast frequencies," *Jour. Res. Nat. Bur. Stan.*, vol. 21, p. 795; December, (1938). (RP1156.)

[15] T. R. Gilliland, S. S. Kirby, and N. Smith, "Characteristics of the ionosphere at Washington, D. C., (1938)." Published each month in PROC. I.R.E., for the second month before.

PROCEEDINGS, and were summarized for the past five years in a paper presented at two meetings.[16] It was shown that average critical frequencies vary directly as sunspot numbers, both having reached a maximum in 1937.

It was demonstrated that there is not[17–19] sufficient ionization at levels only a few kilometers above the ground to account for wave refraction by ionized layers such as reported by several observers in the past two years. The results of a number of researches suggest that such low-level refraction is caused rather by changes of refractive index resulting from variations of water-vapor content, pressure, and temperature, being thus of the same nature as refraction at ultra-high frequencies.

The theory of oblique reflection from ionosphere layers was worked out.[20–22] This makes it possible to calculate maximum usable frequencies and other data for long-distance radio transmission from vertical-incidence ionosphere measurements, and vice versa. This was applied[23,24] to the determination of maximum usable frequencies and skip distances at all times over a series of years, and to the working out of various practical communication problems.

Three separate types of ionosphere disturbance causing radio transmission difficulties were identified and described:[25] sudden ionosphere disturbances; prolonged periods of low-layer absorption; and ionosphere storms. The characteristics and effects of ionosphere storms were notably elucidated by a number of investigations.[26–30] The effects diminish with distance from the magnetic pole and auroral zone.

There was increased recognition[31–34] of the rôle of scattered reflections caused by patches of ionization in and between the regular ionosphere layers. They give rise to a complex type of signals within the skip region and are responsible for some inherent errors in direction finding.

ULTRA-HIGH FREQUENCIES (OVER 30,000 KILOCYCLES)

The development of accurate formulas[1,2] for calculation of field intensities as affected by diffraction clearly showed diffraction to be one of the causes for the absence of a sharp drop of intensity at the horizon. Refraction due to diminishing refractive index with height provides another cause. The effects of atmospheric refraction were shown[35–40] to include not only a substantial increase in received field intensity, but also the production of fading. Within the horizon

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distance there is little fading. Beyond the horizon, as the distance increases, fading becomes more rapid and more intense. The fading is caused by interference between components propagated over slightly different paths in which there are variations of humidity, temperature gradient, etc. Some experiments between 60 and 200 megacycles indicated transmission to be materially affected by air-mass boundaries at heights above ground of two to six kilometers. Measurements of received field intensities show reasonable agreement with theory. The calculated curve of field intensity as affected by diffraction is the lower envelope of the actually measured values of field intensity.

The theoretical work above mentioned refers to vertical polarization. Some unpublished work showed that intensities for horizontally polarized waves are less, except at the highest frequencies.

Because of the instability of received fields at ultra-high frequencies, it is necessary to use very much more transmitting power than would be required otherwise, in order to maintain good reception during periods of low intensity.

An investigation[41,42] of received intensities over a city area showed large variations over a five-megacycle band of frequency, caused by waves arriving over several paths because of reflections from buildings. This may have an effect on television quality because of the wide modulation band used.

Direction finders[43] were successfully developed for ultra-high frequencies. In the course of this development, considerable data on the propagation of these frequencies were obtained.

Ultra-high-frequency equipment was developed for aircraft uses. This includes application to ground-air telephony and radio range beacons. Experiments on 125 megacycles showed more reliable signals than on lower aircraft frequencies.

There was regular long-distance sky-wave propagation on frequencies up to about 45 megacycles by the F_2 layer in the winter daytime.[15] This is characteristic of years near sunspot maximum; it is believed that in years near sunspot minimum ultra-high frequencies exhibit no long-distance transmission. A study[44] of reception in New York of television signals from Europe on frequencies from 35 to 45 megacycles showed substantial agreement with known data on ionosphere characteristics, when differences along the transmission path are allowed for and recognizing the occurrence of sporadic E transmission (next paragraph). The quality of such long-distance television pictures was generally poor because of multiple images produced by multipath transmission.

Besides F_2-layer propagation, there was long-distance sky-wave propagation of frequencies up to about 60 megacycles by sporadic E-layer ionization. The sporadic E occurs[45–47] most commonly in the summer, particularly in the morning and evening, but may occur any time of day or night; it occurs occasionally at all seasons, particularly in the evening. Detailed information on its prevalence is published each month in the PROCEEDINGS by the National Bureau of Standards. It is sporadic or patchy[48–51] both in time and space; its radio manifestations are sometimes called "bursts."

Progress was recorded in the study of the radio possibilities of guided waves at frequencies between 150 and 4000 megacycles.[52–56] This included radiation from pipes and horns and the development of amplifiers and measuring technique for these frequencies.

This report was prepared under the supervision of the Annual Review Committee by the Technical Committee on Wave Propagation of the Institute of Radio Engineers, the personnel of which follows.

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Lateral Disk Recording for Immediate Playback with Extended Frequency and Volume Range*

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Summary—*The equipment for lateral disk recording can be attached to a reproducing turntable and provides means for recording on lacquer-coated disks. The records can be played immediately using a new high-fidelity pickup. The recorder operates on a maximum power of approximately one watt. A sapphire stylus, normally supplied for instantaneous recording on lacquer, is used. When the recommended technique is followed, records can be made comparable in quality with commercially produced transcription records.*

INTRODUCTION

MUCH has been done by experimenters during the past decade toward the development and improvement of means for making records that could be reproduced immediately and yet which would be more durable than soft wax masters. Some of the methods consisted of embossing the blank record with a blunt stylus while others more closely approached the regular procedure for making commercial records in that the grooves were cut by removing with a sharp stylus threads of the material of which the disk was composed. This latter method, although not the least expensive, has come to be accepted as the most useful, providing the highest quality and the lowest surface or background noise.

Fig. 1—Recording and reproducing equipment for broadcast use.

The applications for instantaneous-playback recording, as it is sometimes called, are too varied to enumerate here. It is enough to say that the broadcast and motion-picture-studio users represent a generous percentage of the total. Hence this discussion will be confined to equipment and methods designed to fill especially the requirements of these important fields.

DESCRIPTION OF THE RECORDER

The performance of the immediate-playback recording equipment which has been developed by RCA is summarized as follows: Lateral type of modulation was adopted because of its low distortion characteristics. A frequency range of 50 to 8000 cycles is covered with reasonable uniformity by the recorder head. Recording is done on metal disks coated with a semiplastic material in which the groove is cut by means of a sharp sapphire stylus.

Records of high quality and low noise level have been made with this equipment. A volume range is possible in which the noise measured in an unmodulated groove is 55 decibels below the output of a fully modulated groove in which the total (root-mean-square) distortion does not exceed 5 per cent of the fundamental. These measurements were made without regard for ear characteristics and using the full over-all frequency range specified. The records showed excellent wearing quality and when used in conjunction with a new type of pickup later described, were not noticeably impaired by repeated playings of one hundred times. This is a characteristic of the record material and reproducer. The equipment on which these records were made is shown in Fig. 1, which illustrates a typical broadcast-studio turntable for recording and reproducing.

The modulator or cutting head is essentially a mechanical band-pass transmission network suitably terminated and damped by a special compact mechanical resistance material. The mechanical impedance of the entire moving system is high enough to make the motion of the cutting stylus practically unaffected by the impedance of the plastic record composition. This permits an unloaded or microscopic measurement of the frequency response and general performance of the head, which is duplicated almost exactly when cutting a record. The response-frequency characteristic of the device measured in this manner and converted to lateral stylus velocity, which is proportional to pickup output voltage, is shown in Fig. 2. It will be seen that frequencies below 800 cycles are purposely controlled so as to hold the physical amplitudes constant, the stylus velocity diminishing as the frequency is reduced. This practice is followed generally in disk recording to avoid overmodulation or cutting through to adjacent

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grooves at low frequencies where the amplitudes would otherwise be large. The correction is made by suitable compensation in the reproducing circuit.

In Fig. 3 may be seen the internal construction of the recording cutter together with its equivalent electrical circuit. The elements are illustrated in their respective locations in the mechanical and electrical networks. Since for constant current in the recorder winding, the armature receives a constant force, the electrical circuit is shown working from a constant-voltage source. The output of the mechanical system is represented by the lateral stylus velocity and is equivalent to current through the second inductance of the electrical network. Inspection of this circuit reveals it to have a rising output characteristic with increasing frequency. This compensates for the diminishing current through the recorder winding caused by its inductance.

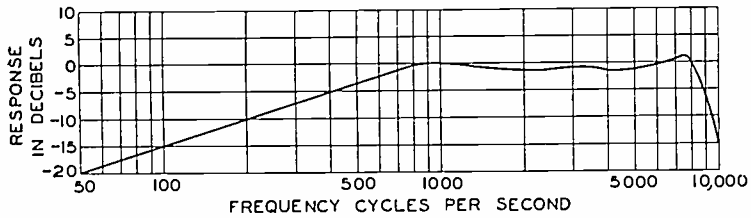

Fig. 2—Response-frequency characteristic of one type lateral-recording head in terms of stylus velocity.

Most mechanical systems which translate electrical energy to mechanical motion and the reverse, introduce some distortion because of the departure of certain factors from an ideal condition. It is far more difficult, for example, to obtain linear mechanical resistances and reactances than electrical. However, the components involved in this method of instantaneous disk recording contribute surprisingly little distortion to the over-all result. This is partly due to the elimination by cancellation of most of the "tracking" distortion because of the lateral method of modulation. The merits of lateral recording have been discussed at length and several excellent mathematical treatments of the subject have been published.[1]

Under normal operating conditions, the over-all root-mean-square total distortion of the combined recording and playback operations is less than 5 per cent. The total harmonic distortion to be expected at 400 cycles at varying degrees of modulation is indicated in Fig. 4. These observations were made at a record speed of 33.3 revolutions per minute and a diameter of 12 inches. It is apparent that a higher recording level can be used at 78 revolutions per minute for the same value of distortion as the increased speed reduces the wave-front slope. What distortion exists can, for the most part, be attributed to tracking failure, or a departure of the pickup stylus motion from an exact copy of the recorded wave. Earlier experiments have supported the theory that most distortion in sound-on-disk work is of this nature rather than due to nonlinearity of the recording and reproducing heads, assuming of course they are well designed. This assertion is further proved by actuator measurements wherein the tracking errors are not involved.

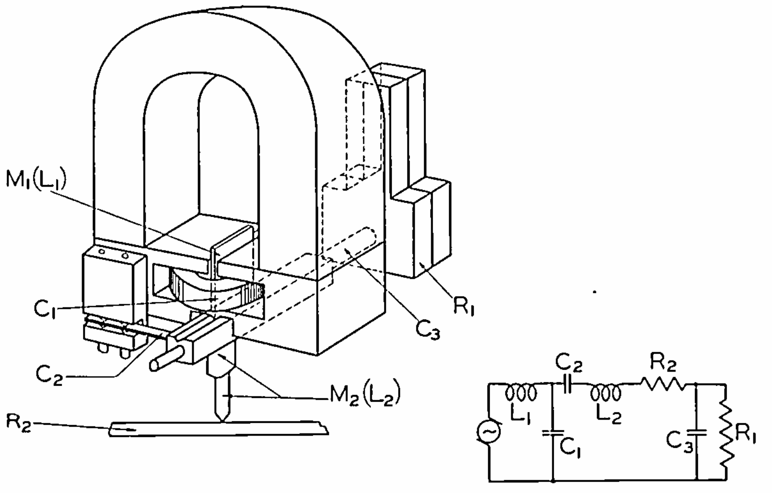

Fig. 3—Mechanical construction of recorder head with equivalent electrical circuit.

Immediate playback systems suffer from a defect which exists in all disk reproduction when there are large changes in record diameter. This is a transfer or high-frequency needle loss due to the finite size of the reproducing stylus, the weight of the pickup, and the softness of the record stock. All these factors contrive to reduce the output of the pickup at high frequencies and when the surface velocity of the record becomes low. The softer the record composition, the greater the loss. This is particularly true of soft composition blanks used for immediate-playback recording which because of their plastic quality appear to

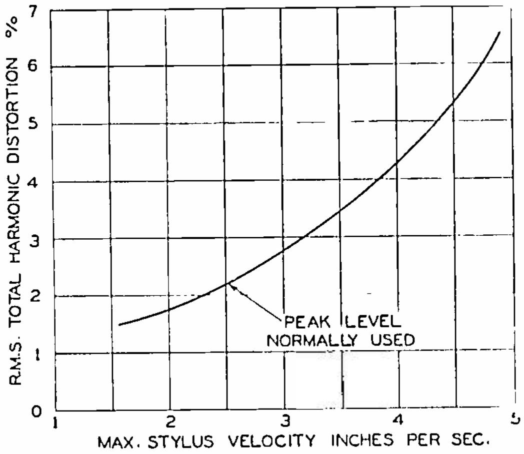

Fig. 4—Over-all total distortion of recorder, record, and reproducer.

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[1] J. A. Pierce and F. V. Hunt, "On distortion in sound reproduction from phonograph records," *Jour. Acous. Soc. Amer.*, vol. 10, pp. 14–28; July, (1938).

have an elastic flow under pressure of the stylus. The average losses for a particular record stock encountered at various diameters at 33.3 revolutions per minute are shown in Fig. 5.

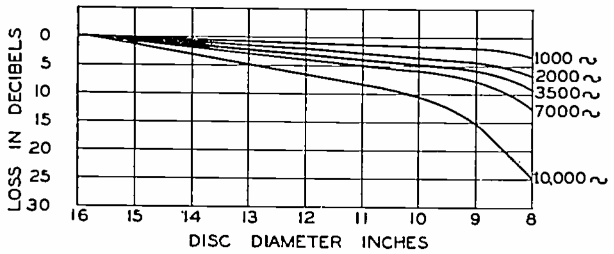

Fig. 5—Translation losses in reproduction from plastic-coated disks.

Much can be done to counteract these losses by utilizing variable compensation during recording and various mechanisms have been suggested to do this automatically, such as adjustable compensators driven by synchronous electric clock motors and the like. However, it has not seemed practicable to attempt full compensation for frequencies higher than 7000 or 8000 cycles because of the severe losses in the upper register as the groove velocity becomes low. Neither does it appear desirable at the present stage of the art to depart from standard groove dimensions. By this is meant that while reducing the stylus radius from the present standard of 0.0023 inch to 0.001 inch, for example, there would be somewhat less transfer loss, the extensive duplication of equipment does not seem justifiable. Recorder heads have been built covering the range to 10,000 cycles and suitable, except for the reasons mentioned, for immediate-playback use. Higher record speeds are, of course, a partial solution to the problem but not an economical one. The transfer losses are less serious on standard records pressed in harder compositions.

Much of the popularity of immediate-playback recording has come as a result of successful duplication of records made by this process. A few copies are ordinarily made by re-recording offering almost no impairment of quality while for a larger number, the original, if not lubricated, can be plated after bronzing or silvering, and master, mother, and stampers produced. Pressings can then be obtained in a variety of materials depending upon the particular requirements involved.

THE LATERAL REPRODUCER

For reproduction there is provided a new lateral transcription pickup of light weight and great flexibility, having a permanent diamond point. The frequency range of this unit is ample for all requirements.

In considering the design of a high-quality transcription reproducer for commercial applications certain specifications must be met without imposing limitations of any sort on associated equipment. The reproducer must be light, flexible, free from resonances, and rugged enough to stand ordinary handling. The response-frequency characteristic should be substantially uniform, flat from 50 to 9500 cycles, and this accomplished without loss of sensitivity so that existing amplifying systems can be used.

The solution of these problems resulted in development of the MI-4856 reproducer, a wholly new design of pickup head and supporting arm. Fig. 1 shows the unit mounted on a studio-type transcription turntable. This reproducer is intended primarily for use on nonabrasive high-fidelity transcription records but may be used on all lateral records having standard groove dimensions, including composition or lacquer-coated disks such as those used for immediate playback. It is equipped with a permanent diamond point, the radius of which conforms to the 0.0023-inch standard. This radius is held to limits, not exceeding ±0.0001 inch, to insure an even distribution of pressure over the curved bottom of a standard groove in order to reduce record wear and resulting noise.

The response-frequency characteristic of the reproducer as determined by employing a standard test pressing 12 inches in diameter running at 33.3 revolutions per minute is shown in Fig. 6. The test record used was made at constant lateral stylus velocity above 800 cycles and approximately constant amplitude from 50 to 800 cycles. The reproducing circuit contains the usual low-frequency compensation so that the output is essentially uniform throughout the range from 50 to 9500 cycles. The characteristic of this compensation network is such that the transmission is increased approximately 5 decibels per octave as the frequency is reduced from 800 to 50 cycles.

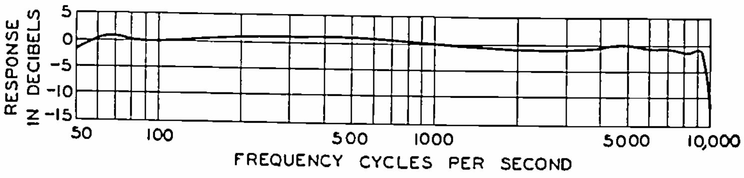

Fig. 6—Response-frequency characteristic of reproducer from test pressing.

In making high-fidelity records, including the majority of composition-coated disks for immediate playback, use is made of what is known as complementary compensation. Because of the energy distribution in most speech and music, it is possible to accentuate the higher frequencies when making a record and attenuate them in reproduction, thereby reducing the surface noise resulting from minute particles in the record stock and dust particles accumulated in the record processing.

Fig. 7 shows the recording and reproducing amplifier response-frequency characteristics and the ideal flat over-all response to which, of course, is added the characteristics of the reproducer. This method of reducing surface noise can be used successfully in most cases without adding appreciable distortion to the reproduction.

The relatively wide frequency range and high output of the new reproducer was obtained by departing from conventional pickup design. The internal construction is shown schematically in Fig. 8. An efficient magnetic circuit having a low-reluctance alternating-current path is built around the armature, which is of the clamped-reed type. While the two upper air gaps are inactive, being filled by nonmagnetic spacers, the stability of the armature is increased permitting the active air gaps to be smaller, so that no output is lost by this construction and much is gained by simplicity and ease of assembly.

The mechanical armature impedance, both stiffness and mass, is too high to be directly coupled to the record. Therefore a linkage having nearly a 6-to-1 leverage ratio or a 36-to-1 impedance ratio is employed. This tremendously reduces both the stiffness and effective mass as seen by the record. The diamond point is secured in the lower end of an extremely light aluminum-alloy pivot arm which is supported in knife-edge bearings, vertically spring-supported but rigid laterally. Thus the pivot arm is permitted to rise during groove "pinching" or when irregularities in the bottom of the groove are encountered, without lifting the entire pickup.[2] But in the direction of the useful motion being transmitted to the armature, the linkage has a minimum of compliance and the upper resonance is high; namely, about 9000 cycles. This peak is reduced by means of a block of loaded rubber arranged as a selective damper tuned approximately to the peak frequency, at which it absorbs energy as a mechanical antiresonance circuit. Being supported only by the armature, it does its work without adding impedance at other frequencies or increasing the stiffness of the reproducer. Consequently the stylus-point impedance is low at all frequencies.

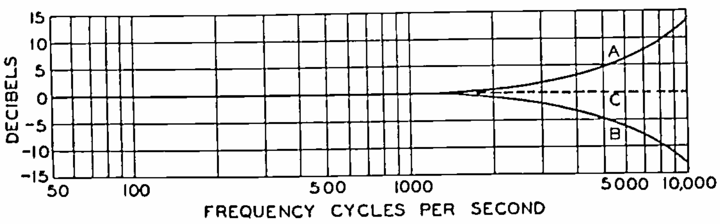

Fig. 7—Recording and reproducing characteristics for reduction of surface noise.

The response of the pickup when working into a resistive load would droop at high frequencies because of the inductance of its winding unless the winding reactance were kept relatively small. This is not consistent with high output. Instead of reducing the inductance for a given value of resistive load, a shunt capacitance is connected across the pickup which by reacting broadly with the inductance, increases the high-frequency response through a large portion of the upper range. The reproducer has a slightly rising characteristic at the upper end, enough to offset high-frequency needle or transfer losses encountered at a mean record diameter of twelve inches at 33.3 revolutions per minute. In this way, it is possible to provide a high-output pickup which, without any compensation other than that normally provided at low frequencies, will reproduce a 12-inch constant-velocity pressing with substantially uniform output to 9500 cycles. At smaller diameters there is some reduction in high-frequency output and a slightly rising response at larger diameters.

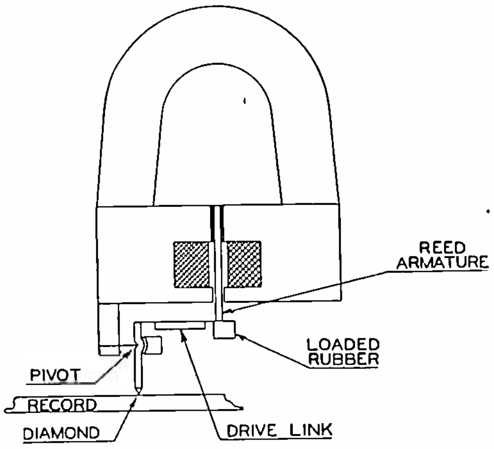

Fig. 8—Schematic diagram of reproducer.

Tests indicate negligible wear of the diamond stylus on nonabrasive records. On shellac-composition records there is sufficient wear at 5000 10-inch faces to justify replacement of the point. This is considerably longer life than that obtained from so-called permanent points of iridium or sapphire, when used on abrasive records with the same pressure, two ounces.

An improvement in pickup tracking has been made by offsetting the head with respect to the arm. This angle, which is about 10 degrees, results in two positions of perfect tangency with the groove, one near the center of the record and the second near the outer edge. The error in tracking angle between these positions is less than 5 degrees.

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[2] Page 17 of reference 1.

A New Antenna System for Noise Reduction*

V. D. LANDON†, MEMBER, I.R.E., AND J. D. REID†, NONMEMBER, I.R.E.

Summary—A discussion is given of a novel antenna system in which a high degree of noise reduction is obtained over a wide frequency band. A feature is the elimination of noise even when the antenna cannot be located in a noise-free area. The apparatus involved is simple and low in cost.

When receiving signals on an ordinary antenna, a considerable portion of the noise encountered is man-made static and arrives on the receiver power cord. This noise current flows to ground through the ground lead but the impedance of the ground lead is practically always quite high and a voltage drop occurs along it. This noise voltage occurring from chassis to ground is, in effect, applied to the input of the receiver. Noise arriving in this manner is by far the most important kind when no attempt at noise reduction has been made.

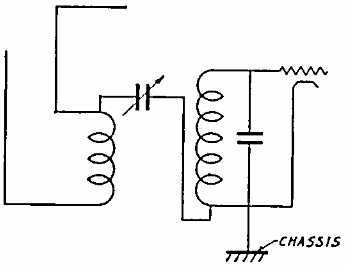

Fig. 1

When an efficient noise-reducing antenna is employed, this type of noise is greatly reduced. The amount of noise remaining is a function of the accuracy of balance of the transmission line and transformers, and of the amount of noise field at the antenna proper. In the average installation, the noise-reducing kit makes a big improvement but the remaining noise is sufficiently high to justify an attempt at further improvement. However, a large share of the remaining noise is pickup on the antenna proper. The relative percentage of noise from antenna pickup and from unbalance will, of course, vary from one installation to another. An adjustable balance of noise picked up on the antenna proper is required if further improvement is to be made.

There are a large number of possible circuits by means of which this adjustable balance may be obtained. These circuits will not be discussed in detail but an attempt will be made to show why the particular circuit to be described was chosen. In choosing the circuit, it is desirable to select one in which the balance adjustment has as little variation with frequency as possible. Also, as little dependence should be placed on balance as possible. In other words, noise reduction should remain good in spite of imperfect balance. Of the circuits tried, the circuit of Fig. 1 seemed to fulfill these requirements best. The arrangement shown in this figure is suitable for long-wave operation only. The modification required for the addition of high-frequency reception is shown later.

In this figure, the antenna consists of an inverted L about 80 feet long. A counterpoise is run parallel to and close beside the antenna for a distance of one half its length. The spacing is not critical but should be about six inches. A primary coil of high inductance is connected from antenna to counterpoise and is coupled to a resonant secondary. A small variable condenser is placed from antenna to chassis and is used to balance out the noise. The theory of operation is as follows:

Noise disturbances on the power line cause a voltage from chassis to ground. A small portion of this noise voltage is transferred to the antenna and counterpoise by capacitive coupling. If the voltages on the antenna and counterpoise are equal, then no current will flow in the primary and no voltage will be induced in the secondary.

This may be more readily understood by referring to Fig. 2 which is the same circuit redrawn to show that the circuit is essentially a bridge. Two of the arms of the bridge are the antenna capacitance and the counterpoise capacitance. A third arm is the distributed capacitance of the lower end of the primary winding to chassis. The fourth arm is the capacitance of the other end of the primary to chassis in parallel with the balancing condenser. The output load impedance of the bridge is the primary winding. Since the capacitance of the antenna is greater than that

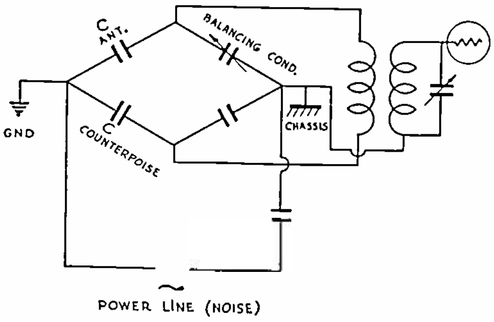

Fig. 2

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* Decimal classification: R320. Original manuscript received by the Institute, June 9, 1938. Presented, I.R.E. Convention, New York, N. Y., June 16, 1938.

† RCA Manufacturing Company, Inc., RCA Victor Division, Camden, N. J.

of the counterpoise, it is evident that the capacitance from chassis to antenna must be made greater than that from chassis to counterpoise if a balance is to be obtained. The balance adjustment is to be made at the time of installation by the service man.

It should be noted that it is not necessary to have the antenna in a noise-free area. If direct capacitance exists between the power line and the antenna, the only result is that a slight readjustment of the balancing condenser is required.

A factor to be avoided is capacitance from the primary to the high-potential end of the secondary. At first sight, even this appears to be harmless, since a readjustment of the balancing condenser regains good noise reduction. Unfortunately, the degree of readjustment required varies with frequency. Thus, the balance point varies somewhat with frequency when capacitance is present from the primary to the high-potential end of the secondary.

In appraising the circuit, it is important to realize that if no capacitance existed between the primary winding and the chassis, then good noise reduction would result even without the balancing condenser. It follows that if the primary capacitance to chassis is small, then fair noise reduction is obtained even with an imperfect balance. A critical balance is required for the best noise reduction, but fair results are obtained even with the balancing condenser omitted.

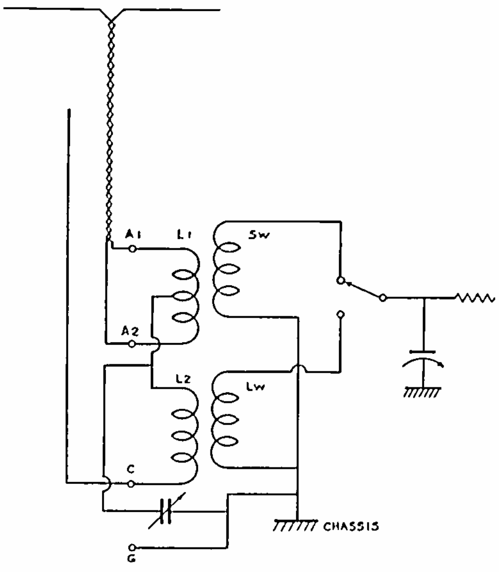

Fig. 3

At low frequencies, the bridge consists essentially of four capacitances and hence the balance point does not vary greatly with frequency. At frequencies close to the fundamental of the antenna, the inductance of the antenna becomes important. As a result, the balance varies badly with frequency and at some points, a balance cannot be obtained at all. For this reason, it is not recommended that this principle be used for frequencies close to or above the fundamental resonance of the antenna.

In Fig. 3, a circuit is shown in which an adjustable balance is used for the broadcast band and a dipole with a transmission line is used for short waves. The dipole and transmission line together act as the broadcast antenna. The broadcast counterpoise is placed alongside the transmission line. The connections are such that no switching is required in the primary circuit.

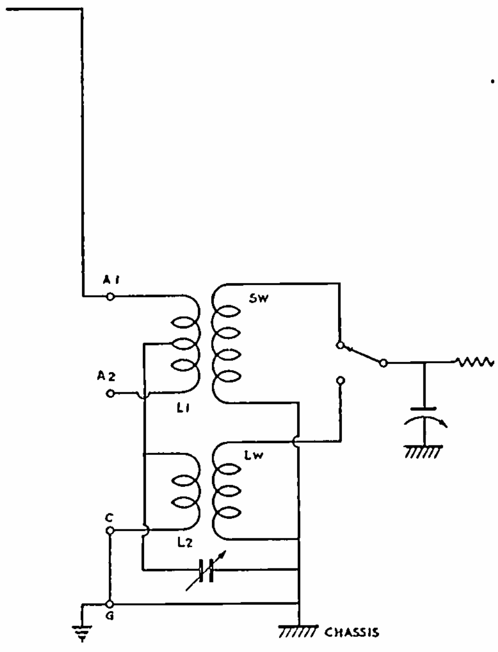

Fig. 4

This arrangement is used as an integral part of the receiver. The balancing condenser and primary windings are mounted on the receiver chassis and add to its cost only by the cost of the condenser, since similar primaries would be required in any case. The antenna kit itself is quite low in cost as it contains no transformers, the wires and insulators being all that are required.

When making an installation of this antenna, the transmission line is cut to length to suit the requirements of the installation. The counterpoise is also cut to an appropriate length so that the required setting of the balancing condenser is about the same in each location. The proper length of counterpoise is one half the length of the transmission line plus ten feet.

The primary system is so designed that satisfactory operation is obtained when used on an ordinary antenna. The connections are shown in Fig. 4. The path for short-wave currents from the antenna is through one half of L_1 and the balancing condenser to ground. L_1 and the balancing condenser have a negligible effect on low-frequency currents which flow to ground through L_2.

The same antenna is also designed for use with receivers not especially designed for it. This requires a transformer external to the receiver because most receivers have one side of the primary grounded. The circuit is shown in Fig. 5. The operation of the primary circuit is about the same as when it is built into the receiver. The only difference is in the resonance point. When the primaries are built into the receiver, the broadcast primary circuit is resonant just outside the low-frequency end of the band, in the conventional way. When an external transformer is used, the broadcast primary and secondary circuits are separately resonant in the band, but are so tightly coupled as to push the peaks to the extremes of the band. A resistor is shunted across the primary to flatten the response. The response curve taken into a 2000-ohm load is given in Fig. 6.

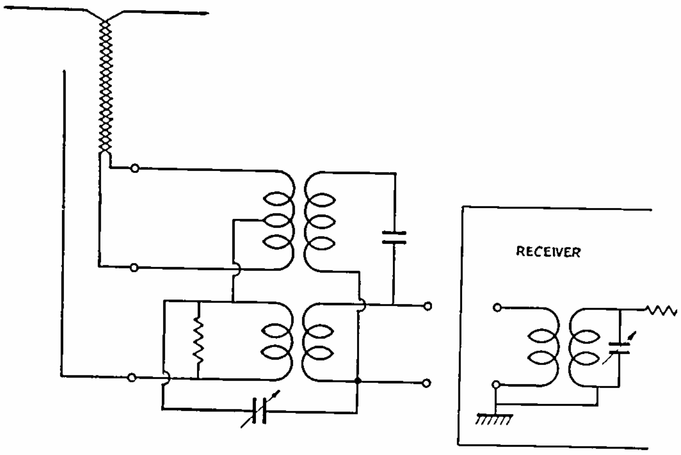

Fig. 5

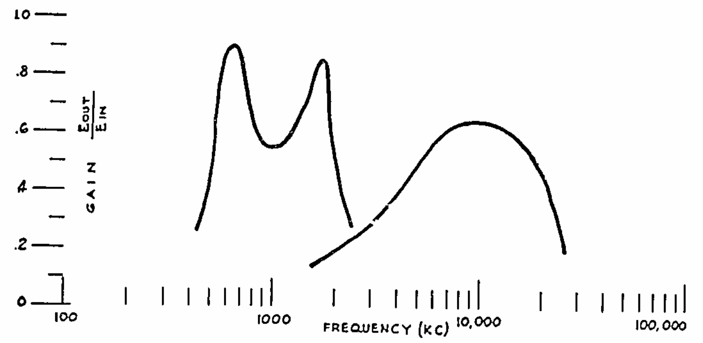

Fig. 6

The high-frequency section of the transformer was designed to match a 100-ohm line to a 200-ohm load. The high-frequency portion of Fig. 6 shows its performance under these conditions.

To evaluate the noise-reduction performance of this antenna system, measurements were made using a setup shown in Fig. 7. A signal from a signal generator is applied to the power cord of the receiver and the sensitivity of the receiver to this signal is measured both with a normal antenna and with the noise-reducing antenna. The ratio of these two sensitivities is a measure of the effectiveness of the noise-reducing antenna. In Fig. 8, a curve is given of attenuation versus frequency. Each point on this curve is the average of four measurements, the method of applying the voltage being either between the line and ground (Method No. 1) or across the line (Method No. 2) and each method being applied at points A and B. Ratios of the same order were obtained for each condition.

The previous circuits have shown only two receiving bands, a low-frequency or broadcast band, and a high-frequency or short-wave band as used on the simpler receiver. A circuit for a three-band receiver having a medium-frequency band intermediate to these afore-mentioned bands is as shown in Fig. 9. This circuit again avoids primary switching which is advantageous, in that it enables the capacitances of primary to ground and to secondary to be kept at a minimum. If an antenna is used, of dimensions suitable for the long-wave band, it is resonant in the medium band, and a balance cannot be obtained on the medium band except at the lower frequencies although there is an improvement in noise reduction over the conventional receiver with the primary

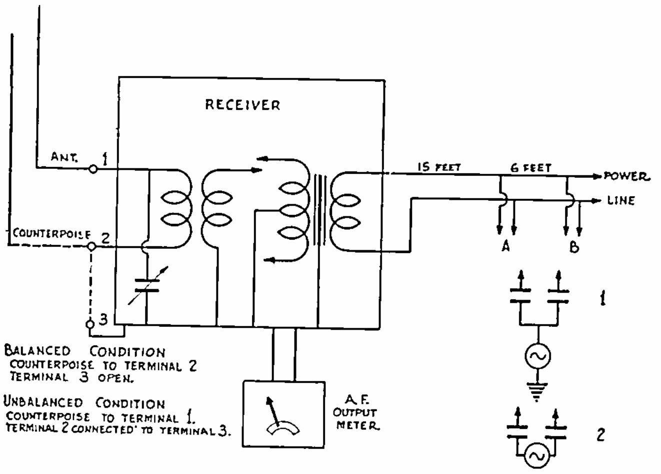

Fig. 7

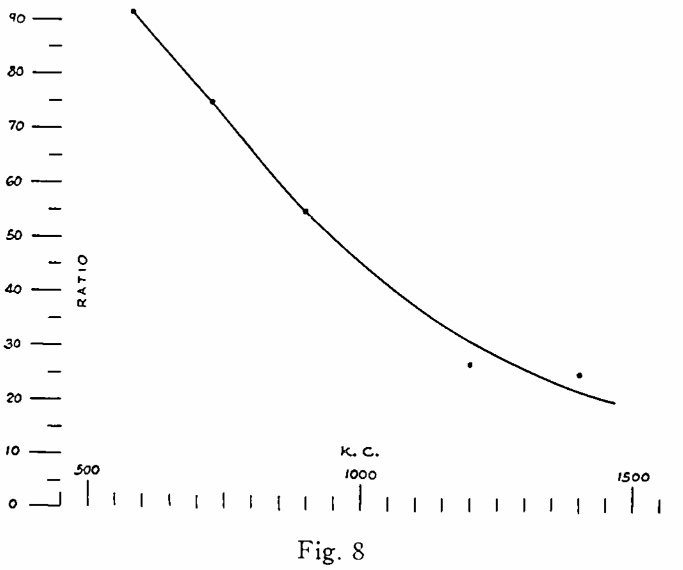

Fig. 8

grounded to the chassis. Fig. 10 illustrates a commercial application of this circuit to a 3-band receiver.

It is of some interest to note that still further improvement in noise reduction can be obtained by using a variable resistor in parallel with the balancing condenser or in series with it. When this is done, a critical adjustment of both resistor and condenser may be found which results in infinite attenuation of the noise from any given source. Noise from a different source sometimes requires a slightly different adjustment. A change in frequency usually means that the balance must be readjusted if any advantage is to be obtained from the resistor. For this reason, the use of the resistor is not considered practicable for general use. It might prove quite valuable, however, in isolated cases where the required noise attenuation could not be obtained by any simpler means.

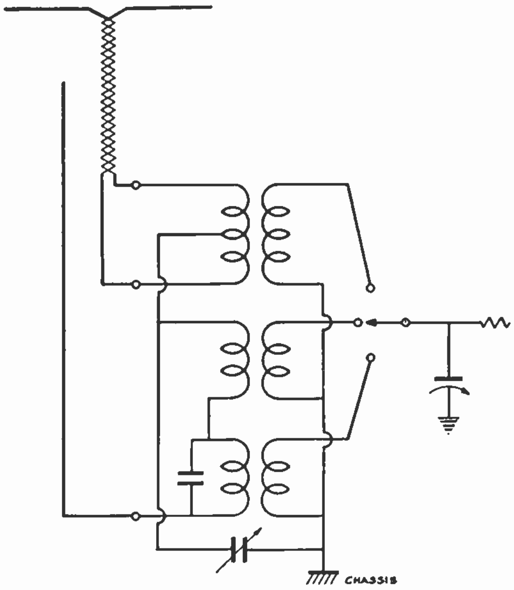

Fig. 9

It is of interest to note the results which can be obtained by using these circuits on receivers having buzzer *B* supply operated from a low-voltage direct-current source. Such a buzzer *B* supply generates radio-frequency interference. This interference gets into the input circuit chiefly by means of currents in the supply leads which cause a noise voltage from the chassis to the ground. This noise may be balanced out in a similar manner to ordinarv power-line noise, in spite of the fact that the noise originates in the receiver itself.

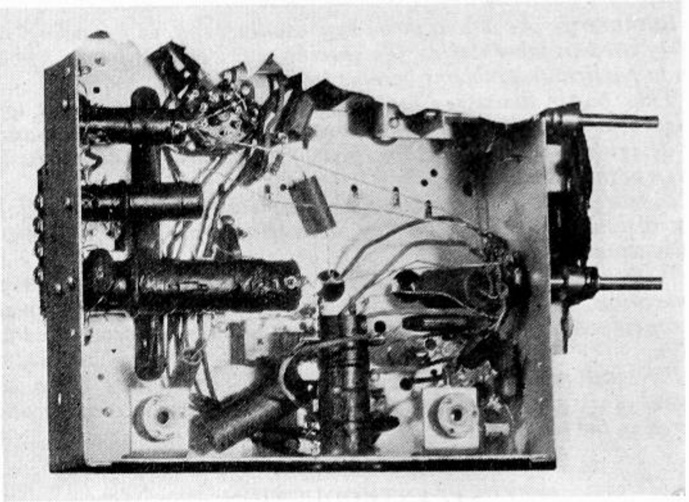

Fig. 10

It is recognized that considerable work has been done by previous experimenters. A partial list of prior art, most of which is available only in patents, is given below for reference.

Fessenden	742,780
Taylor	1,468,049
Conrad	1,513,223
Weinberger	1,738,337
Miller	1,872,487
Loftin	1,995,152
Alexander	2,054,645
Beverage	Re-19,784
DeMonge	British 445,187

Wireless Age, pp. 839–842; July, (1914).
Radio Retailing, p. 63; June, (1936).

Acknowledgment

The authors are indebted to Messrs. W. L. Carlson, W. H. Conron, and D. E. Nason for valuable assistance in designing the apparatus and preparing the paper.

Oscillograph Design Considerations*

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Summary—*As the cathode-ray oscillograph is becoming more widely used in laboratories, the specific requirements for its application to particular problems become important.*

This paper discusses the relation of these requirements to the design of a complete cathode-ray oscillograph. The deflection-amplifier design is discussed with respect to the electrical and mechanical design of the equipment.

Linear sweep-circuit design, the application of grid modulation to transient studies, frequency determinations, and return-trace elimination are discussed.

With regard to the power supply, voltage considerations, ripple elimination, brilliance, amplifier and control-circuit requirements, are considered especially as to their effect upon transformer and filter design.

Physical requirements of the layout of equipment for a commercial unit are examined according to the design considerations covered in the paper.

I. INTRODUCTION

DURING the past few years the cathode-ray oscillograph has developed from an interesting device which possibly could be used for some applications to an indispensable tool in all fields of engineering from research to production. As it becomes more widely used, its advantages and its limitations with respect to the particular problem under investigation are better recognized. While the great flexibility of the high-vacuum cathode-ray tube permits it to be adaptable to many problems, a complete oscillograph, incorporating a linear sweep circuit, and the deflection and modulation amplifiers must be designed with regard to the work for which it is intended.

Depending upon the brilliance desired and the type of cathode-ray tube employed signal voltages ranging from approximately 50 to over 1500 volts will be required for proper deflection. Since most signal voltages are of relatively low amplitude, amplifiers must be employed to obtain adequate deflection amplitude. The introduction of amplifiers brings up the question of both the frequency range and the amplitude of the signal voltages to be studied. Amplifiers are not yet available which cover all frequencies from zero cycles per second to whatever frequency may be desired.

The cathode-ray oscillograph has been so universally used for plotting voltages as a linear function of time that other methods are often forgotten. For many investigations it will be found advantageous to plot the signal as a function of some other voltage which occurs at some particularly interesting portion of the unknown signal wave. In many cases a sinusoid of the same period as the unknown may be employed advantageously to perform this function, since when used for deflection of the cathode-ray tube it will move the electron beam faster at the center of the screen than it does at each end. In other cases some voltage may be available from the equipment under investigation which may be even more advantageous to use for horizontal deflection than either a linear saw-tooth or a sinusoidal voltage.

The type of signal to be studied will have a great bearing upon the fundamental design of the oscillograph. It is preferable, in all cases, in the interests of economy to operate the cathode-ray tube at the lowest accelerating potential possible. The brilliance of any given portion of the pattern on the screen of the cathode-ray tube will be a function of the accelerating potential and the speed with which the spot travels across that particular portion of the pattern. As the speed of the spot increases, the time that it remains on a given screen area decreases, the screen excitation decreases, and therefore the brilliance of the pattern will decrease. When a signal such as a pure sine wave is being studied, the rate of change of voltage over a complete cycle is relatively constant, and even at a low accelerating potential there will be no portion of the pattern where the trace is invisible. If a signal such as a spark discharge is under investigation, however, it will be necessary to use a high accelerating potential in order to study the fine structure of the high-frequency components found in signals of this type.

For most applications a cathode-ray tube employing a willemite screen is used, which has the advantage that it does not burn easily and has sufficient brilliance that all ordinary observations may be made in daylight. When very low-frequency signals are to be studied, however, or when it is desired to study transient signals, the persistence of vision of the human eye is not sufficient to retain the pattern long enough to study the image properly, so a cathode-ray tube having a long-persistence screen is used. The pattern will remain on the screen of the tube after the spot has traveled across the screen, for a time determined by the acceleration voltage applied to the cathode-ray tube and by the speed of the spot.

When the curve is recorded upon a film, moving at a constant rate and providing the time axis, the

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† Allen B. Du Mont Laboratories, Inc., Passaic, N. J.

persistence of the pattern on the screen would be objectionable, and it is desirable to use a tube with a screen having a very short-persistence characteristic.

II. Amplifier Design

Since the oscillograph is a measuring instrument, the power drawn from the circuit under test should be at a minimum. At the same time, the input circuits of the unit must have provision for attenuation of the signal to a value which may be handled by the amplifier input circuits without distortion. These requirements demand a high-impedance voltage divider. The simplest method of obtaining this would be to employ a high-resistance potentiometer in the grid circuit of the input amplifier. The use of a potentiometer, however, has serious disadvantages as shown in Fig. 1. C_1 represents the stray circuit capacitance between the input and the grid. C_2 represents the total of stray circuit capacitance and tube input capacitance. When the slider is moved to the high side of the potentiometer, C_1 becomes infinity and has no effect upon the circuit. The high-frequency response of the circuit will be affected only by C_2 and there will be a constantly decreasing gain as the frequency is raised. For any other setting of the potentiometer, the capacitances C_1 and C_2 will influence the voltage division, so that at only one setting of the potentiometer arm will there be a division of voltage irrespective of frequency.

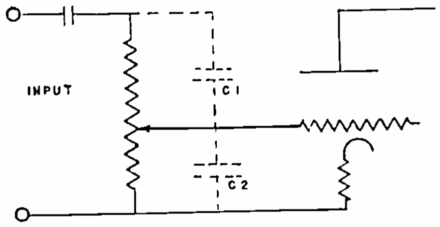


Fig. 1—Input-attenuator distortion.

To control these stray capacitances a fixed divider may be employed using fixed resistances and capacitances to give predetermined attenuation ratios. A number of these fixed dividers may then be selected by a suitable switching arrangement to obtain a number of attenuation ratios. One step of such a divider is shown in Fig. 2. C_1 is made just large enough to permit it to maintain control over the stray circuit capacitances and yet keep the total shunt capacitance of the input at a minimum. C_2 is proportioned for proper capacitive division of the signal in the same ratio as determined by R_1 and R_2.

It would be obviously impractical, however, to build an attenuator with a sufficient number of steps to satisfy every requirement. To obtain smooth gain control without affecting the frequency response of the amplifiers, this control should determine the gain of the amplifier itself. One method is shown in Fig. 3.

The potentiometer R is arranged across a suitable voltage source to vary the bias on one of the grids of the amplifier tube. The amplification factor of the tube will be a function of the potential applied to this grid. Further simplification is provided in this method in that since the control carries no signal its physical location will have no effect upon the frequency-response characteristics of the amplifier.

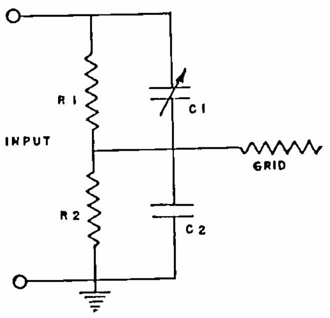


Fig. 2—Capacitive correction of input attenuator.

Many cathode-ray-oscillograph-amplifier designs require flat frequency-response extending down to only a few cycles per second, necessitating the use of unusually large time constants in the resistance-capacitance coupling circuits between the various stages. When the gain of a stage is varied in the manner described above, the plate current of the tube which is controlled is also changed. However, it takes a considerable time for the coupling condenser to assume its new charge because of the long time constant of the coupling circuit. As a result, when this change is amplified by the following stages it may be so great as to shift the beam off the screen, and a number of seconds may elapse before the beam returns to its original zero position.

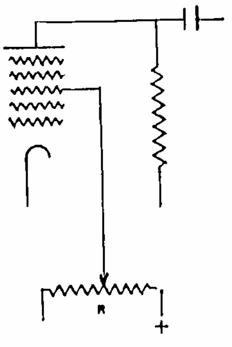


Fig. 3—Method for fine gain control.

There are two methods available to correct this difficulty and in practice both of them must be employed. One method is shown schematically in Fig. 4. The plate-grid coupling circuit C_2–R_3 has had its time constant reduced so that the time required for the coupling condenser to reach a new steady-state value after a change in plate current of the first stage is comparatively small. The consequent loss of low-frequency response of the amplifier resulting from this decrease in time constant of the coupling circuit is equalized by the network C_1–R_2. Here the plate resistor has been divided into R_1 and R_2 with the lower section R_2 by-passed to ground with C_1. This method of plate-circuit compensation for low frequencies has found quite general use in video-frequency amplifiers for television use where much the same problem is encountered.

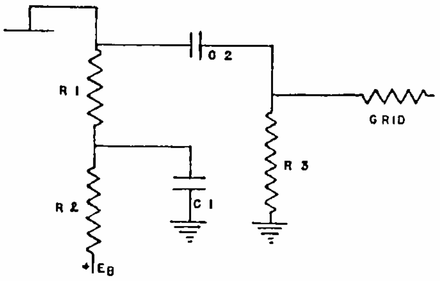


Fig. 4—Plate-circuit compensation.

The above methods of controlling the gain of the amplifier to operate between the steps of the resistance-capacitance input attenuator will always cause a certain temporary shifting of the position of the spot as the amplifier gain is changed. This will have no effect upon the operation of the instrument, but it will prove annoying when fine adjustments of the gain are to be made frequently. In order to avoid this trouble, the signal component only of the amplifier plate voltage may be operated upon. This may be accomplished as shown in Fig. 5. Here, condenser C decouples the direct-current component of the plate signal from the gain control, and this control operates to vary the amount of signal transferred to the following stages. Frequency discrimination, as discussed above, will take place in this type of control but may be reduced, however, to a very small value by using a potentiometer of small total resistance. The potentiometer will then maintain resistance control of potential division in spite of the stray circuit capacitances. Resistor R_2 is provided to limit the range of the control to a three-to-one ratio and prevent the operator from overloading the input circuit of the first stage. The time constant of circuit C, R_1, R_2 will necessarily be comparatively short, and plate-circuit compensation, as shown in Fig. 4, must be provided to correct the low-frequency response of the amplifier.

The amplifiers for a cathode-ray oscillograph are required to supply relatively little power to the deflection plates of the cathode-ray tube, but their voltage output must be rather large to obtain full-scale deflection at high accelerating potentials. For a cathode-ray tube operating at an accelerating potential of 3000 volts, the amplifiers will be required to deliver a peak-to-trough voltage swing of approximately 800 volts, and if the oscillograph is to operate with a single-stroke sweep circuit, which will be described later, they must be capable of twice this value. To obtain these voltage swings, the amplifiers must operate at high plate-supply voltages. If only low-frequency response is required, the plate-load resistance may be kept high and small receiving-type amplifier tubes may be used, provided they have sufficient voltage insulation. When the amplifier range is extended to frequencies above approximately 15 kilocycles, however, the plate-load resistance must be reduced to minimize the shunting effect of stray circuit capacitances. In this case, the amplifiers must be capable of dissipating large amounts of power as well as providing large voltage swings for full-scale deflection of the cathode-ray tube.

To obtain the large voltage swings necessary for deflection of the cathode-ray tube, it is desirable to use push-pull deflection amplifiers. This type of amplifier has a number of advantages over the single-ended amplifier. Some cathode-ray tubes have one plate of each pair of deflecting plates connected to the final anode. If this type is operated at high anode voltages, the large voltage swings necessary to give full-scale deflection cause the free deflection plate to influence the operation of the electron gun. As this plate reaches the peak of the cycle where its potential difference with respect to the final anode becomes of the order of a few hundred volts, serious defocusing of the beam will occur. The acceleration due to this free plate is also responsible for the "keystone" distortion found in cathode-ray tubes operated in this manner. It may be possible to adjust the electrode voltages so that the beam is in focus at the center of the screen, but the edges of the pattern will always remain out of focus. With push-pull deflection of the beam the plates are excited out of phase and only half of the voltage swing will be required on any one plate as compared with asymmetric deflection. A further saving is effected by the use of push-pull deflection in that the necessary power-supply voltage for the amplifiers to obtain full-scale deflection is

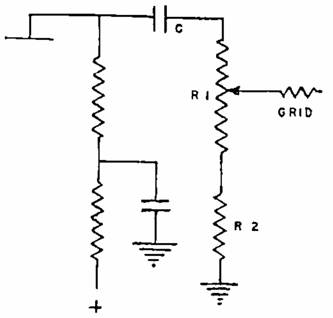


Fig. 5—Method for fine gain control.

halved. Since a large part of the amplifier power for cathode-ray tube deflection is dissipated in tube plate circuits and in bleeders, the power consumption of the unit is considerably reduced by lowering the power-supply voltage to half the value required for asymmetric deflection.

Many oscillograph applications require the use of a linear time base for the horizontal axis. It is preferable, in most cases, to obtain the saw-tooth voltage for this deflection from a source having a low-voltage output since it is difficult to generate a large voltage with this wave shape, having a wide frequency range without the use of complicated correcting circuits and very high-voltage power supplies. The amplitude of horizontal deflection may be readily controlled with the amplifier gain control without any effect upon the frequency of the sweep circuit. It has been found empirically, however, that the frequency range of an amplifier which will satisfactorily handle saw-tooth signals should extend to at least ten times the highest and one tenth of the lowest sweep frequency it is to handle. Because of the slow rate of rise of voltage during the forward portion of the sweep, the rate of change corresponds to a sinusoid of much greater period than the fundamental period of the saw-tooth. The sweep amplifier must, therefore, be capable of passing a sine wave of at least one tenth the frequency of the saw-tooth signal. The return-trace portion of the sweep must necessarily be very fast in order to avoid confusion of the pattern. This part of the saw-tooth, therefore, involves very high-frequency components. To keep the return trace of the spot fast, the amplifier must offer very little attenuation to signals of at least ten times the frequency of the saw-tooth.

III. Sweep-Circuit Design

At the present time, the gas-discharge type of sweep circuit, using a gas-filled triode as a relaxation oscillator is used almost exclusively as a generator of saw-tooth voltages for linear sweep circuits. This type oscillator has the advantage that it is very easily synchronized, and it may be operated over a wide frequency range with a minimum number of controls.

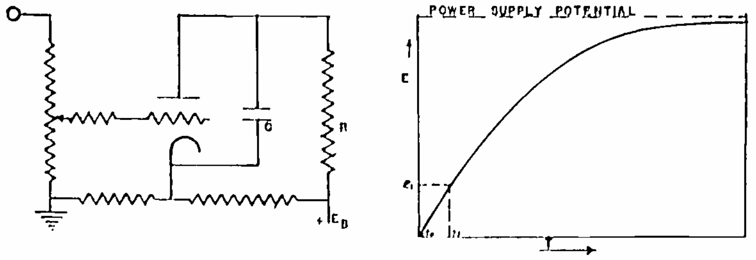


Fig. 6—Gaseous-discharge-type sweep circuit.

The fundamental circuit of a saw-tooth oscillator is shown in Fig. 6. The bias of the discharge tube is determined by a tap on the bleeder resistor. This bias determines the breakdown potential of the plate circuit and, therefore, the output voltage. Condenser C is charged through resistor R, and its voltage at any time follows the ordinary logarithmic curve of a condenser charging through a resistor, as shown in Fig. 6. The condenser is allowed to charge, however, only to the potential e_1. At this point the voltage across the condenser is equal to the breakdown potential of the discharge tube and the tube short-circuits the condenser and reduces its voltage to approximately zero, at which time another cycle of operation begins. The portion of the logarithmic curve which is thus used varies essentially linearly with time and a saw-tooth voltage is developed.

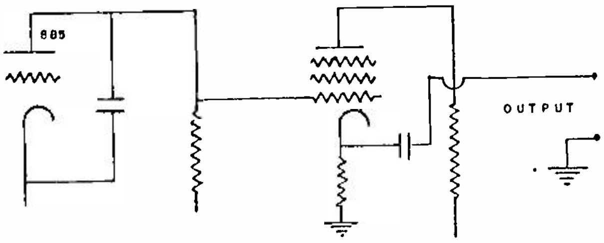


Fig. 7—Impedance-matching stage.

Since only a small portion of the complete charging curve of the condenser is used, the amplitude of the output of the oscillator is relatively small, and it must be amplified to provide sufficient voltage for deflection of the cathode-ray tube. The current-handling capacity of such tubes as the Type 885 which are available for this service is relatively small, and the resistance R must, therefore, be of the order of a few megohms to prevent overloading of the discharge tube. In addition R must be large when the oscillator is to operate at very low frequencies.

These two limitations require a relatively high-impedance plate circuit for the saw-tooth oscillator. When this plate circuit is connected to the input of an ordinary oscillograph amplifier, the loading introduced by the input circuit will produce serious distortion of the saw-tooth voltage and cause it to vary nonlinearly with time. Any amplifier input circuit having an impedance high enough to prevent the introduction of nonlinearity of the saw-tooth wave would cause frequency discrimination in the attenuator. This would produce frequency distortion of the signals and cause a long horizontal tail to appear on the trace of the cathode-ray tube at the end of the sweep.

One method of eliminating the distortion due to this impedance mismatch is to employ an impedance-matching amplifier as shown in Fig. 7. This amplifier tube has its grid directly connected to the plate of the oscillator tube, and it presents as a load only its own grid impedance. Since the impedance-matching amplifier feeds into the regular deflection amplifier of the oscillograph it need only have a gain of about unity. This low gain may be obtained by lowering the plate-circuit impedance of the tube to a point where any loading produced by the deflection-amplifier input circuit will have negligible effect upon the linearity of the saw-tooth signal. This type of direct coupling to the plate of the discharge tube also reduces the stray circuit capacitances so that the upper frequency limit of the time-base oscillations, which is limited by these capacitances, may be raised.

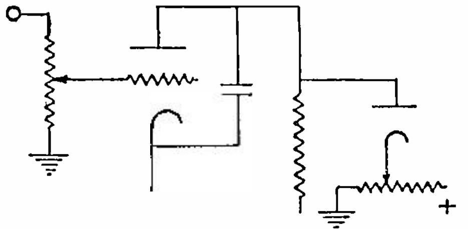


Fig. 8—Method for single-sweep control.

For many studies of transients it is desirable to make a photographic record of the wave. To prevent the film from becoming overexposed along the zero line while awaiting the transient, the arrangement shown in Fig. 8 may be employed. Here a diode has been connected from the plate of the discharge tube to ground. The cathode potential of the diode may be adjusted by means of a potentiometer to any value between ground and a positive maximum greater than the plate potential of the discharge tube. As long as the diode cathode is maintained positive with respect to its plate there is no loading effect upon the discharge-tube plate circuit. If, however, the diode cathode be adjusted to the point where the diode just starts to draw plate current, the plate circuit of the discharge tube will never reach the breakdown potential required to operate. The breakdown potential may, however, be controlled by the voltage on the grid of the discharge tube. If a pulse be applied to the grid of this tube to reduce its breakdown potential to a point where it may discharge, one single sweep will take place. If no more pulses are received by the discharge-tube grid, the diode will again regain control and the oscillation will stop. For the study of transient signals, the pulse to initiate the single sweep may be taken from the initial portion of the transient or it may be obtained from some other source which will initiate the sweep just previous to the start of the transient.

When this single sweep is used the beam is positioned to one side of the screen of the cathode-ray tube. It is, therefore, necessary for single-sweep operation that the amplifiers have capacity for twice full-scale deflection of the cathode-ray tube in order that full-scale deflection be obtained when the spot is positioned to one side. The inclusion of a single-sweep circuit in a cathode-ray oscillograph must amount to a fundamental change, since this requirement of twice full-scale deflection capacity for the amplifiers affects the entire amplifier and power-supply design.

IV. Grid Amplifier

Practically all transient studies which are made with the oscillograph must be provided with some type of time axis for measurement of the duration of the signal. It has been quite common practice when using the cathode-ray oscillograph first to make a photograph of the timing axis and then record the transient. This method is subject to variations in the equipment which will always leave the possibility of doubt in regard to an exact reproduction of the horizontal time axis in the two cases.

By the use of a grid-modulation amplifier in the cathode-ray oscillograph, a timing signal may be applied to the grid of the cathode-ray tube simultaneously with the application of the transient. This timing signal may be adjusted to make small light or dark dots on the pattern whose horizontal projections will furnish a standard time axis for the transient. By plotting the unknown signal and the timing signal simultaneously, the effects of any variations of the sweep circuit will be eliminated.

The grid-modulation amplifier in the cathode-ray oscillograph may also be used for elimination of the return trace of the spot. As shown in Fig. 9, a small condenser C may be used to couple the grid circuit of this amplifier to the plate circuit of the discharge tube. This condenser may be so proportioned that it will pass only the return trace, or high-frequency component, of the signal at the plate of the discharge tube. This signal is then amplified and fed to the grid of the cathode-ray tube where it cuts off the beam while the spot is traveling through the return-trace portion of the sweep. The phasing of this elimination signal must be proper for blanking rather than intensifying the return trace.

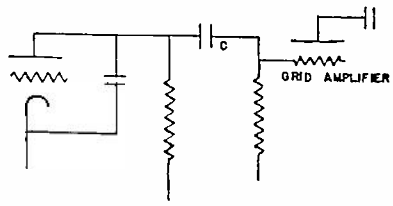


Fig. 9—Return-trace elimination.

V. Cathode-Ray-Tube Control

Depending upon the type of signals which are to be studied with the cathode-ray oscillograph, present design trends have indicated the use of either 1000 or 3000 volts accelerating potential for the cathode-ray tube. For examination of recurrent signals of frequencies high enough to permit the persistence of vision of the human eye to take effect, a potential of 1000 volts is usually used. For studies of low-frequency signals and transients where a screen having a long-persistence characteristic is to be used it is necessary to employ 3000 volts accelerating potential.

The deflection plates of the cathode-ray tube are the measuring circuit of the instrument. Safety requirements make it necessary that they remain at ground potential, or as near ground potential as the signals will permit. In order to prevent defocusing of the beam, the deflection plates must maintain a potential averaging around the final anode potential. For this reason the positive side of the power supply for the cathode-ray tube is grounded. The grid circuit of the cathode-ray tube must then be at full power-supply potential "below" ground and any signals coupled to the grid circuit must be fed through a condenser of sufficient voltage rating to withstand the sum of the power-supply and signal voltages.

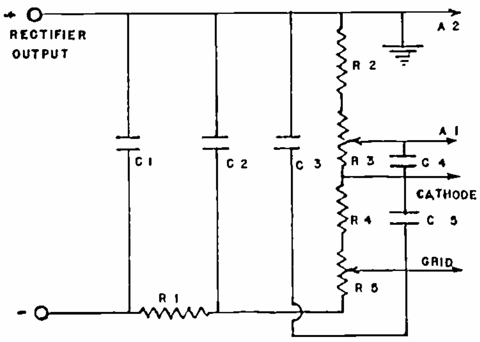


Fig. 10—Cathode-ray-tube bleeder.

Filter requirements for the cathode-ray-tube power supply must necessarily represent a compromise between cost and performance. Since the positive of the power supply is grounded, any ripple voltage will appear on the grid of the tube and cause modulation of the beam. The beam current drawn by cathode-ray tubes is of the order of only a few hundred microamperes, and a resistance-capacitance type of filter will prove much more satisfactory and cheaper than one employing inductance. Fig. 10 shows a representative type of filter and bleeder design for a cathode-ray oscillograph. Condensers C_1 and C_2 and resistance R_1 comprise the usual resistance-capacitance filter. Condenser C_3 has been connected directly to the grid of the cathode-ray tube. This connection permits utilization of the unused portion of R_5 for additional filtering of the power-supply ripple. Condenser C_3 is essential to maintain the ripple modulation of the grid at a minimum. Condensers C_4 and C_5 have been provided to decouple the first anode and the cathode of the cathode-ray tube and eliminate modulation of the beam at these points.

It is often desirable, when photographing patterns from the screen of the cathode-ray tube, to open the shutter of the camera and prepare for taking the photograph without exposing the film. For such work a beam switch such as shown in Fig. 11 may be provided. Potentiometer R_1 represents the usual focus-control potentiometer in the high-voltage bleeder. Switch S, which is the beam switch, is arranged to connect the first anode to either the focus potentiometer or to the cathode through the resistor R_2. When the first anode is connected to R_2, its potential is reduced to a point where the beam is cut off. This method of controlling the beam is advantageous for photographic work since the oscillograph may be preadjusted and the beam turned on or off without disturbing the settings of either the focus or the intensity controls.

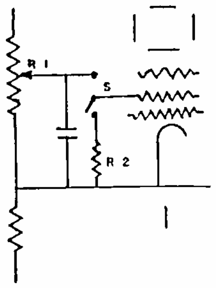


Fig. 11—Beam switch.

It is desirable in all cathode-ray oscillograph equipment to provide means for location of the zero axis of the spot along both the horizontal and vertical axes. When studying asymmetric signals it is convenient to position them to the center of the screen since their amplitude may be then raised to fill the entire screen. It is also necessary in all cases to provide for relocating the spot in the center of the screen whenever the equipment is moved since the earth's magnetic field may shift the spot. Whenever a single-stroke sweep circuit is used, position-control circuits must be provided to move the spot to the edge of the screen of the cathode-ray tube. It is advantageous to employ symmetric positioning of the beam as shown in Fig. 12 in order to prevent defocusing of

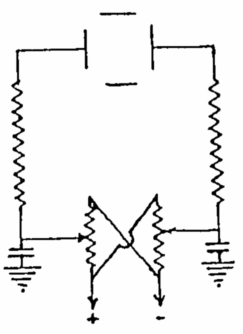


Fig. 12—Symmetric position control.

the beam at the edges of the screen. Symmetric positioning produces the same advantages of uniformity of focus which are obtained from symmetric deflection amplifiers, and both are essential to produce uniform focus over the entire screen area of the cathode-ray tube.

VI. AMPLIFIER POWER SUPPLY

In order to prevent circuit interaction at low frequencies and to maintain uniform frequency response at high frequencies, the bleeder circuits and the amplifier plate circuits must be of low resistance. The high currents drawn by these circuits and the necessity for good regulation require the use of a low-impedance power supply. The high internal resistance of high-vacuum rectifiers causes so much interaction that it is necessary, in most cases, to resort to the use of mercury-vapor rectifiers. For the same reason, the power transformer must have low internal resistance. Ripple voltage in the output of the amplifier power supply must be kept at a minimum, since there is very little filtering action obtained from the low-resistance plate loads of the amplifiers and electrostatic deflection of the beam from the power-supply ripple must be eliminated.

Power-transformer requirements for cathode-ray oscillograph applications differ, in many respects, from those for other communication applications. The cathode-ray tube is affected not only by the voltages applied to the deflection plates, but also by any stray electrostatic or electromagnetic fields which may be present. When the power transformer and the filter choke coils are mounted in the same cabinet with the cathode-ray tube, they must be designed with unusually low stray magnetic fields. To keep these fields at a minimum, 60-cycle transformers may be wound on a 25-cycle stack of high permeability steel. The high currents drawn by oscillograph amplifiers greatly increase this problem of elimination of stray transformer fields. Power-transformer insulation should be capable of withstanding the sum of the output voltages of the cathode-ray-tube power supply and the amplifier power supply, since one is operated with a positive ground and the other with a negative ground. It is desirable to incorporate electrostatic shields in the power transformer which completely surround the primary and the heater winding for the cathode-ray tube. Electrostatic shields surrounding the primary neutralize the capacitance of the high side of the winding to ground and keep the case of the equipment at ground potential. The grounded electrostatic shield surrounding the heater winding for the cathode-ray-tube heater, eliminates capacitive coupling of the winding to other high voltage windings. This capacitive coupling, if it were not eliminated, would cause distortion of the pattern by cathode modulation of the beam at the power-supply frequency.

VII. PHYSICAL LAYOUT OF THE OSCILLOGRAPH

The various components of the cathode ray oscillograph must be physically arranged to obtain the greatest convenience of operation. All operating controls should be located on the front panel, and they should be logically grouped so that all related controls are near each other. A convenient method is to place all vertical controls on one side of the panel and all horizontal controls on the opposite side. Controls for the cathode-ray tube may be located along the top of the panel, and sweep- and grid-circuit controls may be located logically in the center. Input terminals for the horizontal and vertical amplifiers, the sweep circuit, and the grid circuit should be located on the front panel.

Some applications of the oscillograph require that the cathode-ray tube be deflected directly with the input signal without the use of amplifiers. Provision, therefore, should be made at the back of the unit for direct connection to the deflection plates. A binding-post strip located at the base of the cathode-ray tube may be used. Connections to this strip should be as short and direct as possible in order that high-frequency signals connected at this point will not be seriously attenuated.

The amplifiers and power supply are usually arranged on the chassis with one deflection amplifier running from front to back along each side. The power supply must be located at the extreme rear of the unit in order that the magnetic field of the power transformer and choke coils will cause no deflection of the beam. The power transformer should be located completely behind the cathode-ray tube, and it should be oriented so that its field has minimum effect upon beam deflection. Experience has indicated that the use of metal shielding sufficient to eliminate the magnetic field of the power transformer would increase the weight of the unit to a point where it would become no longer portable.

As in all electrical problems, the design of a cathode ray oscillograph represents a cumulation of compromises to accomplish a particular objective. For many uses, many of the features discussed above may be eliminated and for other applications some of them will have to be covered in greater detail, since its usefulness and efficiency in any particular application is dependent entirely upon the manner in which it is used.

An Improvement in Constant-Frequency Oscillators*

G. F. LAMPKIN†, ASSOCIATE MEMBER, I.R.E.

Summary—A simple oscillator circuit is described in which, by means of impedance transformation, the tube impedances are made small relative to those of the tuned circuit. As a result all frequency variations inherent in the tube are reduced by a factor of ten, or more. The method is applicable to oscillators throughout the range from audio to ultra-high frequencies.

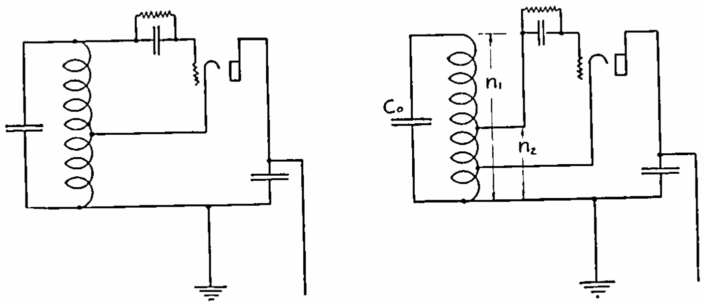
IN THE more recent literature regarding constant-frequency oscillators Llewellyn[1] has shown that it is possible to add reactance, external to an oscillator tube, which will stabilize the oscillation frequency. In the electron-coupled oscillator Dow[2] obtained stability by isolating the load from the frequency-determining circuit and by balancing voltage-frequency coefficients. Groszkowski[3] described a stable dynatron oscillator in which the tube automatically was maintained in a fixed condition of operation.

The stabilization method outlined in this paper was developed during studies on a heterodyne-type frequency meter. In such an instrument a prime requisite is a variable-frequency oscillator possessing a high order of stability. However, the stabilization method is simple and immediately applicable to oscillators in many other fields such as, for instance, conversion oscillators in superheterodyne receivers and oscillators for transmitter frequency control.

A useful concept in regard to stability of oscillators is that of relative magnitudes of impedance. An oscillator in general consists of a tube exciting a tuned circuit. The frequency of oscillation depends upon the net impedance of the tube and circuit in combination. The impedance of the tuned circuit itself very nearly can be fixed, since it depends chiefly on physical dimensions. Then any method which will minimize the impedance of the tube relative to that of the circuit will result in greater stability. This will be true for variations from tube to tube, for variations in a given tube due to changes in temperature, operating voltages, physical dimensions, and aging, and for variations in load applied through the tube.

The concept can be applied directly to a crystal-controlled oscillator in which the crystal functions at series resonance. The tube capacitance lies in series with, and is several hundred times larger than, the equivalent resonant capacitance of the crystal. Any fractional change of capacitance in the tube appears, in the combination, reduced by the ratio of crystal-to-tube capacitance and can vary the oscillation frequency only slightly. In the well-known *hi-C* oscillator the tube capacitance is effectively in parallel with a much larger lumped capacitance, so that fractional changes in the tube are a relatively small part of the whole.

In Fig. 1 is shown a method whereby the tube impedance may be reduced relative to the circuit impedance. At (a) there is drawn a Hartley-type oscillator, where one side of the circuit is grounded for convenience and the tube is connected across the entire circuit as is usual. At (b) the tube is tapped down into the coil and includes only a portion of the circuit. Consider for instance δ, the temperature coefficient of frequency due to the tube interelement capacitances. If we let



(a) (b)

Fig. 1

(a) Common Hartley-type oscillator.

(b) Basic ratio-coupled oscillator for reducing relative impedances of tube.

C = effective tube capacitance across n_2 turns,
α = change in tube capacitance per unit capacitance per unit temperature,
C_0 = circuit capacitance,
n_2/n_1 = ratio of tube turns to total turns,

and have perfect transformer action in the coil, then

$$\delta = \left(\frac{n_2}{n_1}\right)^2 \frac{\alpha C}{2\left[C_0 + \left(\frac{n_2}{n_1}\right)^2 C\right]}. \tag{1}$$

Or, closely, since $(n_2/n_1)^2 \cdot C << C_0$,

$$\delta = \left(\frac{n_2}{n_1}\right)^2 \frac{\alpha C}{2C_0}. \tag{2}$$

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* Decimal classification: R355.9. Original manuscript received by the Institute, June 14, 1938.

† Lampkin Laboratories, Bradenton, Florida.

[1] F. B. Llewellyn, "Constant frequency oscillators," Proc. I.R.E., vol. 19, pp. 2063–2094; December, (1931).

[2] J. B. Dow, "A recent development in vacuum tube oscillator circuits," Proc. I.R.E., vol. 19, pp. 2095–2108; December, (1931).

[3] Janusz Groszkowski, "Oscillators with automatic control of the threshold of regeneration," Proc. I.R.E., vol. 22, pp. 145–151; February, (1934).

For the circuit of Fig. 1(a) the factor $(n_2/n_1)^2$ is equal to unity. In the circuit of Fig. 1(b), entirely practical arrangements permit the quantity $(n_2/n_1)^2$ to become as small as 0.05. The reduction applies not only to temperature effects but generally to the influence of the tube on the oscillation frequency.

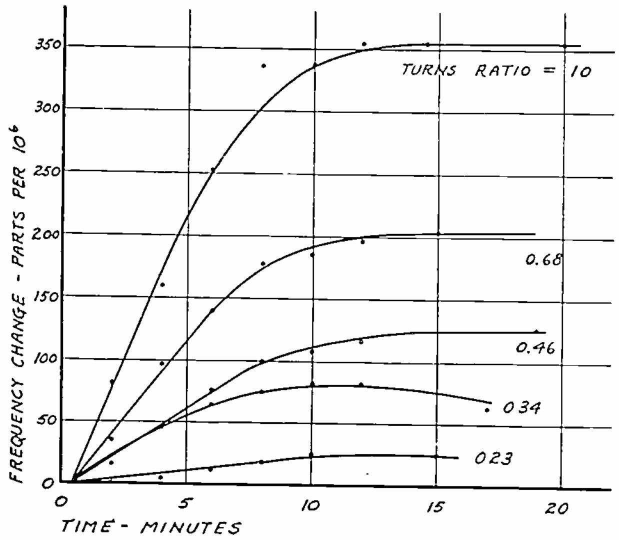

Fig. 2—Frequency variation in an oscillator immediately after being energized, with ratio of tube-to-total turns as a parameter.

An arrangement in which the impedance of the tube is thus reduced, relative to that of the circuit, might be termed a ratio-coupled oscillator.

A simple experimental method of determining the effect of tube temperature on oscillation frequency is to measure the drift during the warming-up period. If the components are laid out breadboard fashion very little heat is communicated to the coil, condensers, and resistors during the time it takes for the tube to reach temperature equilibrium. This time is of the order of 15 to 20 minutes, and over that period the ambient room temperature can be held substantially constant. In Fig. 2 are plotted curves showing frequency variation immediately after energizing an oscillator tube. The tube was a 6J7 laid out in the basic circuit of Fig. 1(b), operating on a frequency of 2450 kilocycles. The ratio of tube-to-total turns was varied as a parameter, and for each condition the cathode tap was maintained at the center of the included turns. An effort was made to begin readings 30 seconds after applying operating voltages in order to have a common origin for the curves.

In Fig. 3 are plotted the points of total drift, during tube warm-up, against the square of the turns ratio. The points should fall on the dotted straight line passing through the origin if the reduction in drift were proportional to the square of the turns ratio. The divergence may be due to the method of taking the time origin, or to imperfect transformer action in the single-layer solenoid coil. Also plotted in Fig. 3 are points showing the frequency shift due to a 10 per cent change in line voltage, as a function of the turns ratio. The entire power supply for the oscillator was derived from the line, so that the 10 per cent change applied alike to filament, plate, and screen-grid voltages. No particular effort was made to adjust circuit values in order to obtain voltage compensation effects. Readings were obtained by noting the frequency, changing the line voltage, and again noting the frequency after approximate constancy was reached in two to three minutes. Each point is the average of several cycles of such change. The agreement between these frequency-shift points and the square-law line is better than for the temperature-drift data. However, for the purpose at hand the important point is that the influence of the tube on the oscillation frequency can be reduced 10 to 15 times.

As the tube is tapped down into the coil a point is reached where it tends to take off into parasitic oscillation at a frequency determined by the inter-element capacitances and the included turns. Suppression methods common to transmitter practice are effective in eliminating such parasitics. Usually a noninductive resistor having low distributed capacitance will be found sufficient if connected close to the oscillator grid or anode. The optimum value ranges from 50 to 25,000 ohms depending on the operating frequency and circuit conditions. The ratio-coupled oscillator has been found uniformly satisfactory in improving stability throughout the range from audio frequencies to ultra-high frequencies. The usable ratio varies from 0.2 to 0.5,

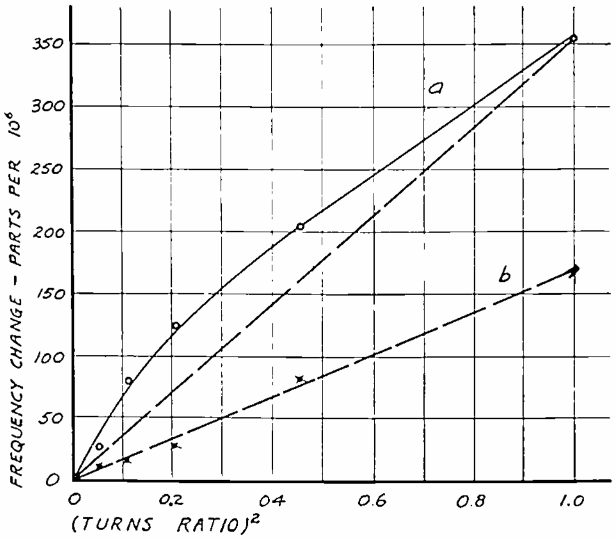

Fig. 3

Line *a* shows the net frequency drift in an oscillator after being energized.

Line *b* shows the frequency shift in an oscillator due to simultaneous 10 per cent increment in all operating voltages.

the former applying to high-Q tuned circuits and the latter to loaded oscillator circuits.

A typical distribution of temperature-frequency coefficients in an older frequency meter using a 24A tube in a common circuit is as follows: tube, +80 parts; coil, +24 parts; condenser, +4 parts, yielding an over-all coefficient of +108 parts per million per degree centigrade. With a 6J7 ratio-coupled oscillator the distribution is: tube, +7 parts; coil, +24 parts; condenser, +4 parts, or a net of 35 parts per million per degree centigrade. In the latter case the chief sources of error lie outside the tube and are more amenable to correction by the equipment designer. If automatic temperature compensation[4] be used, the action inherently is more precise since it does not involve the cancellation of large quantities. The ratio-coupled oscillator as a foundation appears to make possible self-contained heterodyne-type frequency meters with commercially usable accuracies to better than 0.01 per cent.

[4] G. F. Lampkin, "Automatic temperature compensation for the frequency meter," *QST*, vol. 17 pp. 16–19; October, (1933).

Peak Field Strength of Atmospherics Due to Local Thunderstorms at 150 Megacycles*

J. P. SCHAFER†, MEMBER, I.R.E., AND W. M. GOODALL†, MEMBER, I.R.E.

Summary—*Atmospherics in the 150-megacycle frequency range were investigated with a broad-band receiver and cathode-ray-tube scanning technique. The results are of general interest in connection with the problems of atmospheric noise interference on various types of ultra-short-wave radio-communication channels. Some of the conclusions are:*

(1) The peak intensity of disturbances varies 20 decibels between different storms at the same distance. (2) The inverse distance relation is a good approximation for the calculation of the variation of peak disturbance with distance, for any distance and height of receiving antenna likely to be used in a commercial system. (3) The use of high instead of low receiving antennas increases the signal-to-disturbance ratio almost directly with height for storms within 10 miles. (4) The durations of some of the narrower peaks in any particular lightning discharge are at least as short as a few microseconds. (5) The maximum peak field strength of disturbances for a storm 1 mile distance is 85 decibels and for a storm 10 miles distant is 65 decibels above 1 microvolt per meter at a frequency of 150 megacycles with a band width of 1.5 megacycles.

The technique of observations provided a visual indication of the noise interference which might be expected with television signals. It appears that with signal field strengths, such as might reasonably be expected, atmospherics due to thunderstorms will be noticeable for ultra-short-wave television transmission at times when storms are in progress near the point of reception.

Introduction

RADIO transmission at ultra-high frequencies has become increasingly important during the last few years. As far as we know, measurements and observations of atmospheric field strengths in this frequency range have hitherto been only of a qualitative rather than of a quantitative nature. The more-or-less prevalent attitude of workers in this field seems to have been that natural static at frequencies in the ultra-short-wave range can be ignored in interference problems.

Whether or not external noise sources are interfering in nature will depend to a large extent upon the point of view of the observer and the strictness of the requirements of the particular system being considered. It is rather obvious that if any form of natural static would cause objectionable interference it would be that due to local thunderstorms. Based on this hypothesis, a quantitative study of atmospheric field strengths was made during the year 1936 at the Deal, New Jersey, radio laboratory.

While most of the work was performed at 150 megacycles, a few observations were also made at 70 and 850 megacycles. These results seem to be consistent with the 150-megacycle results if due allowance is made for changes in receiver band width and operating frequency.

The results on 150 megacycles and a band width of 1.5 megacycles indicate that lightning flashes 15 miles distant from the receiver may cause peak field strengths of the order of 1 millivolt per meter, and a storm 5 miles distant may give intensities of 3 millivolts. Whether or not such disturbance is of practical importance depends upon the signal-to-noise requirements of the system in use.

The object, in these studies, was to obtain information not only concerning the amplitude of the disturbance voltages but also to obtain some idea as to their character and duration. The visual method of observation which was chosen involved the use of a cathode-ray tube substantially as a peak-voltage-measuring device. The scanning technique employed was similar to that commonly used in television. The peak field strengths of the disturbances were determined from measurements and calibrations of the apparatus employed.

From the information thus obtained it may be possible to estimate the relative interfering effect of atmospherics on various types of ultra-short-wave communication services. There is no analysis of this in this paper.

Apparatus

A schematic block diagram of the apparatus is given in Fig. 1. The cathode-ray tube has a 9-inch face. It is electrostatically focused and gives a spot which would be small enough to resolve a 200- or 240-line picture. It probably does not give enough light for a good television system, and the grid-voltage—beam-current characteristic, Fig. 2, is not as linear as would be desirable but this was not im-

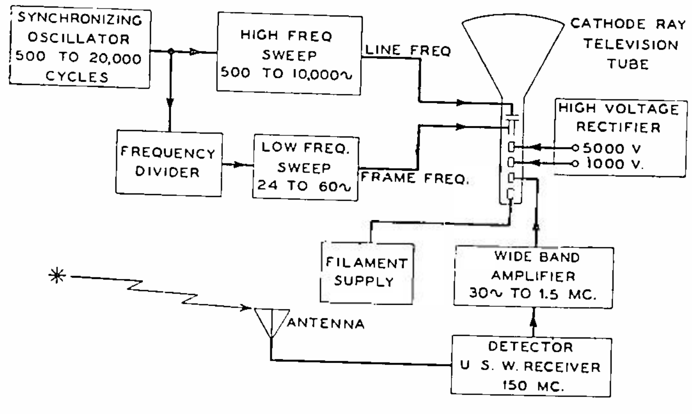

Fig. 1—Schematic block diagram of apparatus used for atmospheric noise studies at 150 megacycles.

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* Decimal classification: R.114. Original manuscript received by the Institute, June 23, 1938. Presented, I.R.E.-U.R.S.I. meeting, Washington, D. C., April 29, 1938.

† Bell Telephone Laboratories, Inc., Deal, N. J.

portant from the point of view of these measurements.

For these studies the receiving equipment used consisted of an ultra-high-frequency receiver[1] followed by a diode detector and wide-band low-frequency amplifier. The over-all system from the antenna to the modulator grid of the cathode-ray tube could be adjusted to give a flat band width (within a fraction of a decibel) from about 30 cycles to over 1.5 megacycles with a maximum gain of 100 decibels. A photograph with the receiver on the right and cathode-ray equipment on the left is shown in Fig. 3. On top of the receiver may be seen the antenna panel, which contains a number of jacks, and the antenna or input attenuator which is of the variable capacitance type. By means of special plugs and patch cords, it is possible to connect the receiver, attenuator, 150-megacycle input test oscillator, and three separate antennas together in a variety of ways.

Three vertical antennas, all of them nondirectional in the horizontal plane, were used. Two were simple half-wave doublets, one about 12 feet and the other about 75 feet above the ground. On the basis of this difference there should be a 16-decibel height gain for the high over the low antenna for signals from a distant transmitter. The third antenna was a 6-tier vertically directive system, also at a height of 75 feet. This vertical directivity gave about 6-decibel power gain over a single half-wave vertical and was such that the antenna had a null at about 20 degrees from the ground. All of these antennas were used with a balanced open wire line between the antennas and the building. Unbalanced coaxial 80-ohm cables were used to connect from the outside of the building to the antenna panel. At the antennas and at the building short lengths of balanced line of the proper impedance were used to match impedances. The transmission lines were grounded at the building by means of quarter-wave grounding loops for lightning protection, and to eliminate noise arising from static charges on the antennas.

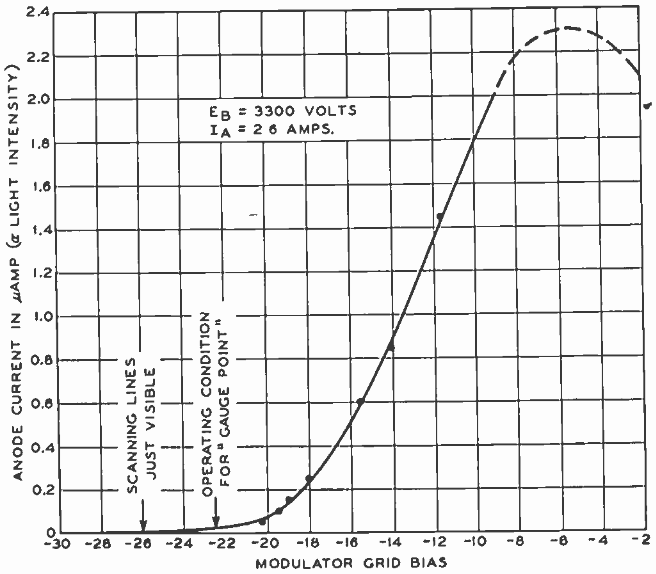

Fig. 2—Cathode-ray-tube characteristic. Anode beam current versus modulator grid bias.

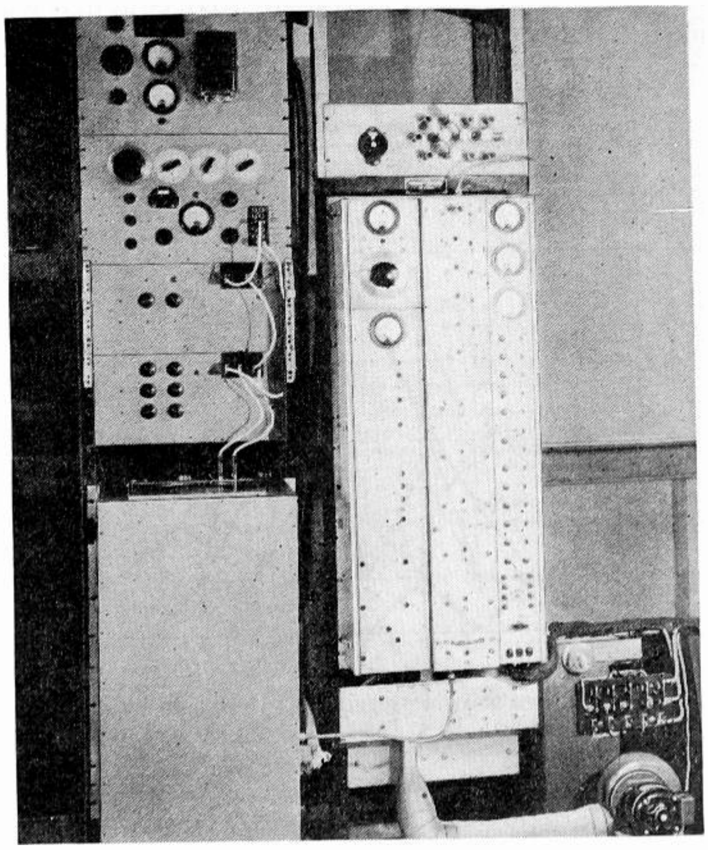

Fig. 3—Photograph of apparatus. Receiver with antenna switching panel on right and cathode-ray-tube equipment on left.

Vertical antennas were chosen in preference to horizontal antennas for use in these experiments in order to avoid any directional effect in the horizontal plane so that storms equally distant in any direction from the receiver would give equal disturbing effects. The difference, if any, in the disturbing effect due to the different polarizations of horizontal and vertical antennas is probably small as lightning strokes are extremely variable in their direction of travel and though for any given stroke one or the other type of antenna might give a greater response, the average for any appreciable number of strokes would probably not be very different.

A number of different tests were made to make sure that the apparatus was functioning properly. These included polar-diagram tests on the antennas, field-strength calibration of antennas, gain measurements of the high-frequency receiver and the wide-band low-frequency amplifier as well as over-all gain and band-width measurements. Where possible, two independent methods of measurement were used in

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[1] The ultra-high-frequency receiver used in these tests was built and furnished us by the courtesy of G. Rodwin and L. M. Klenk of these laboratories.

order to check the results. No detailed results of these apparatus tests are presented in this paper but it is believed that the tests were extensive enough to insure reasonable accuracy in the field-strength observations.

MEASURING TECHNIQUE

In an experiment of this kind where a number of variables are present it is difficult to decide just what kind of data should be obtained. This difficulty is accentuated by the shortness of time available for observation since at this location the number of thunderstorms per year averages only about thirty. Fig. 4 shows the actual number which occurred during 1936. As a result of the experience gained in preliminary tests during the summer of 1935 it was felt that every storm should be observed with one set of standard conditions and that other special tests should be made on one or more storms to try to find answers to some of the numerous problems involved.

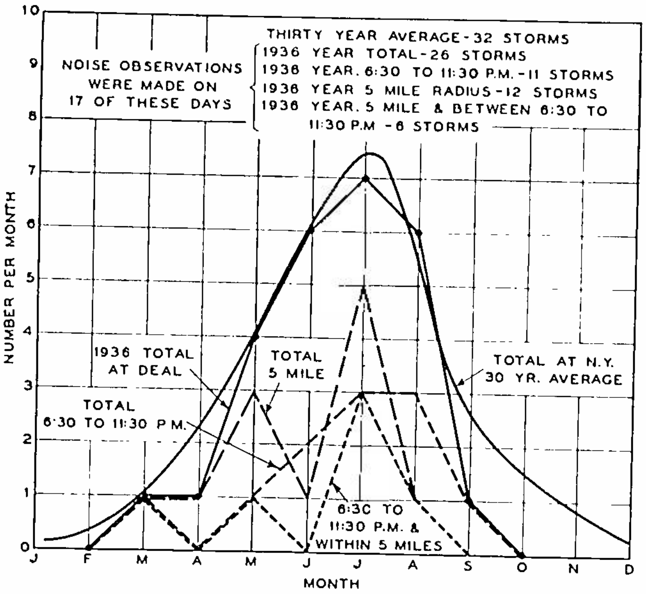

Fig. 4—Curve showing number of thunderstorms each month at Deal, New Jersey, during the year 1936.

The standard conditions which were chosen for observation on all storms corresponded to reception of atmospheric disturbances without the presence of a radio-frequency signal and for this condition the scanning field on the cathode-ray tube was adjusted to a near-black condition by the proper direct-current bias on the modulating grid. The peak static disturbances would then cause white spots to occur on a black background. (This operating condition is marked "gauge point" in Fig. 2.) The scanning lines usually used gave a 135-line field with a repetition rate of 30 per second.

The method of observation, for any given storm condition, consisted in adjusting the attenuators in the receiving system so that the visible disturbance on the observation screen was brought to a predetermined standard condition which we have termed the "gauge point." For this condition the visible disturbance did not occur more than about three times per minute and consisted of small spots which were not present on a total of more than 3 or 4 lines at any one time. The duration of these individual spots varied between 1 and 25 microseconds and they were of sufficient intensity to be readily visible to the observer at about one foot distance. These peaks have been found by measurement with a peak voltmeter on the modulator grid, to have an amplitude about 12 decibels less than the modulator voltage necessary to give full brightness.[2]

Although the small spots visible on the screen for this condition were only of small duration the actual over-all duration of any particular lightning discharge is of the order of 0.01 second. The amplitude of the voltage impressed on the antenna varies throughout the discharge and consists of many peaks of varying duration. What is measured at the gauge point is the amplitude of the highest peaks and the minimum duration of these peaks as limited by the over-all pass band of the system which was 1.5 megacycles. If a 3- or 4-megacycle system were used the sharpest peaks would possibly be narrower and higher. This gauge point may be too strict as far as tolerable interference is concerned if we were considering the effect on actual television pictures.

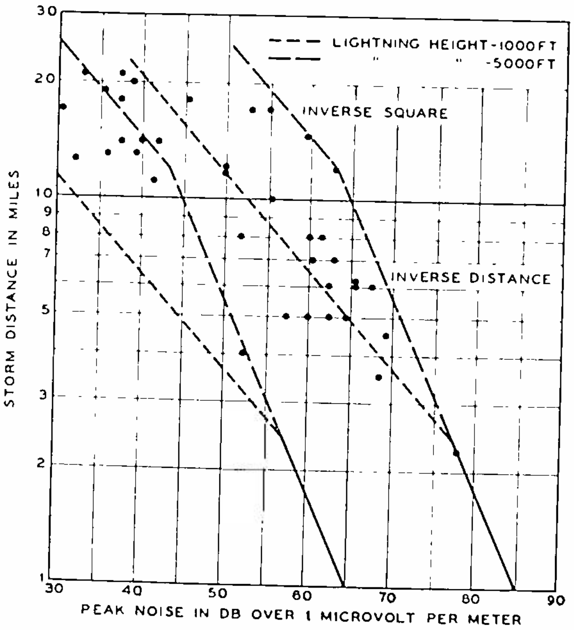

Fig. 5—Chart showing peak field strength of atmospheric noise due to thunderstorms as a function of storm distance at 150 megacycles. Measurements were made during 17 storms in 1936 using a receiver having a pass band of 1.5 megacycles. The receiving antenna was a half-wave vertical dipole, 12 feet above ground.

At the time when the gauge point was determined or as close to it in time as was possible, the distances

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[2] If a truly linear cathode-ray tube were used instead of one having a curved characteristic (see Fig. 2) it is probable that it would respond to atmospherics about 10 decibels weaker than those visible with this tube at the gauge point.

between the lightning discharges and the receiver were determined from the time required for the sound of the thunder to reach the receiver after the flash was visible. Under favorable conditions it was possible to determine this distance up to about 12 miles. The data recorded were the attenuation in the receiver, the storm distance, and the time the measurement was made. From calibrations of the antennas, using a standard field generator, and from gain measurements of the high-frequency and low-frequency equipment it is possible to determine the peak field strength of the static disturbance as a function of distance of the lightning discharge. These results for the three different antennas are plotted on Figs. 5, 6, and 7 and represent the data obtained during the summer of 1936.

The two dipole antennas, one at a height of 12 feet and the other at a height of 75 feet, have very little directivity in either the horizontal or vertical direction. There is a null directly upward but for all practical cases for storms further than one or two miles away this has no effect and the peak field strength recorded is a true measure of the field for signals coming in at any angle.[3]

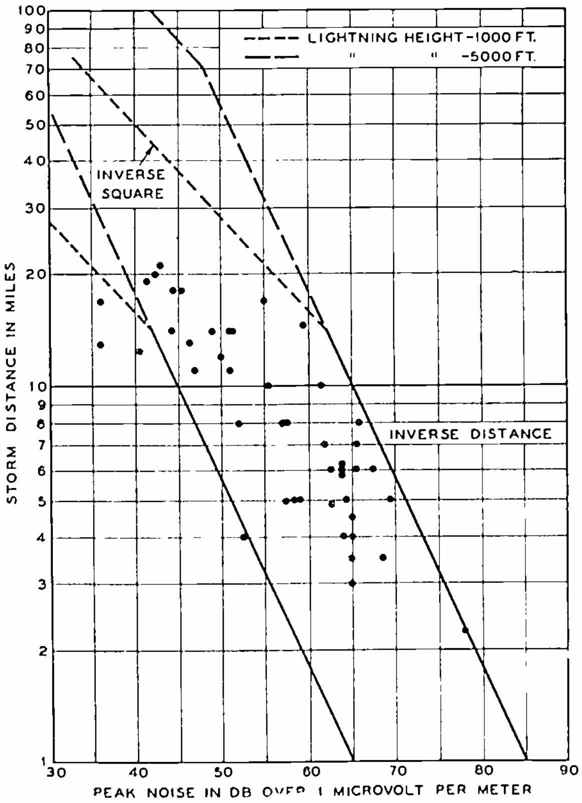

Fig. 6—Chart showing peak field strength of atmospheric noise due to thunderstorms as a function of storm distance at 150 megacycles. Measurements were made during 17 storms in 1936 using a receiver having a pass band of 1.5 megacycles. The receiving antenna was a half-wave vertical dipole, 75 feet above ground.

For near-by storms where the disturbance arrives at a considerable angle with the horizontal, the directivity of the 6-tier antenna in the vertical plane may lead to a response considerably less than that for an equally strong wave arriving horizontally. The data points plotted for this antenna on Fig. 7 are in terms of field strength of an equivalent wave arriving horizontally. For distant storms where the interference arrives from the horizontal direction the field strength measured with the two 75-foot antennas should be the same, while for close storms where the interference arrives at an angle the equivalent field strength for the directive antenna should be less than that for the dipole. The results of the experiments are consistent with this expectation.

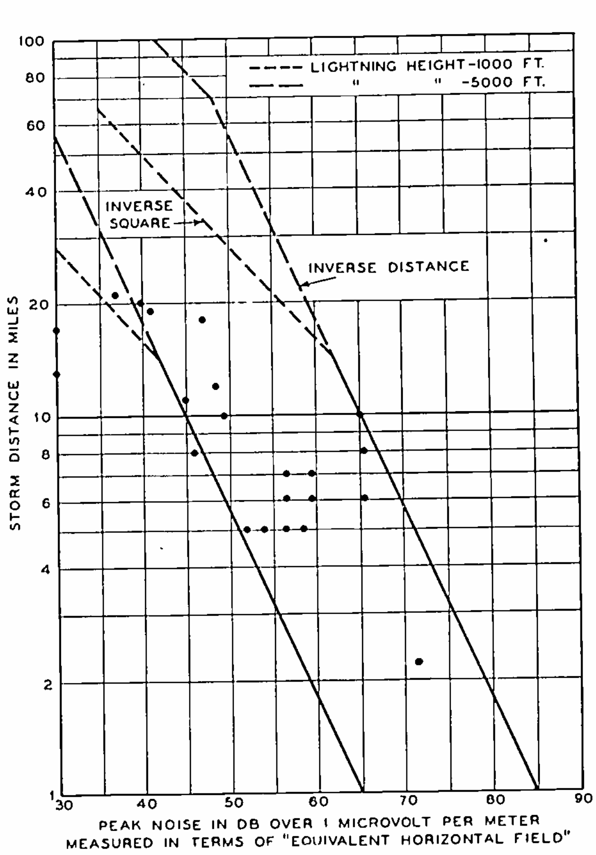

Fig. 7—Chart showing "equivalent horizontal peak field strength" of atmospheric noise due to thunderstorms as a function of storm distance at 150 megacycles. Measurements were made during 10 storms in 1936 using a receiver having a pass band of 1.5 megacycles. The receiving antenna was a 6-tier vertical array having a 6-decibel horizontal gain and a null at 20 degrees. The center of the antenna was 75 feet above the ground.

Discussion of Results

(a) *Static Field Strength*

It is seen from a study of Figs. 5, 6, and 7 that there is a large variation in the peak intensity of storms for any given distance, amounting to about 20 decibels. These variations are probably caused by changes in polarization due to the fact that lightning strokes occur in any plane between the vertical and horizontal (i.e., cloud to ground or cloud to cloud) as well as by actual variations in current flow of the

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[3] Local tests using a standard field signal generator showed that the pickup on the transmission lines was over 30 decibels below the signal picked up by the antennas themselves.

various discharges and perhaps to a variation in the number of discharges per minute.

If we consider the mass plot of the data it is somewhat difficult to determine the actual slope of the line which gives the variation of intensity with distance but for each case some slope between inverse distance and inverse square of distance would give a fair approximation to the correct value. From consideration of the various factors involved and from the alternate assumptions that lightning strokes may occur anywhere between 1000 feet and ground or between 5000 feet and ground, certain calculations have been made. We find that for peaks the inverse distance law should hold for distances up to 14 miles for 1000-foot strokes and 70 miles for 5000-foot strokes, for a 75-foot antenna height; and 2.4 or 12 miles, respectively, for a 12-foot antenna height. Beyond these distances the inverse square law should be approximately correct. Such lines have been drawn on the three curve sheets with a spread of 20 decibels and it is seen that these lines include all but a very few of the data points.[4] It will also be noticed that the inverse distance lines for all three antenna conditions have been drawn to pass through the same co-ordinates, which means that on the average for all storms there is no difference between the field strength of static as indicated by these three antennas.

It was also found when a direct comparison was made between the three antennas for a particular time and storm that in general the response in the receiver was about equal, for distances between 2 and 10 miles. This means that the equivalent horizontal field was the same for the 2-dipole antennas but was about 6 decibels lower for the directive antenna. For the longer distances this condition was sometimes true but more frequently the response from the directive antenna was about 6 decibels stronger than the response from the dipole antenna at the same height, and the latter was 6 decibels stronger than that from the dipole at 12 feet. This means that at distances over 10 miles the equivalent horizontal field was the same for the two 75-foot antennas and was 6 decibels stronger than for the 12-foot antenna. Results such as these are to be expected when the direction and height of lightning discharges as well as the antenna directional patterns are considered.

For all practical purposes, for close storms where the disturbances will be important, a decided advantage in signal-to-noise ratio will be obtained in using high receiving antennas and vertically directive antenna gain as this will increase the effective received signal more than the strength of the disturbance. As far as horizontal directional gain in receiving antennas is concerned there will be no advantage in signal-to-noise ratio when the storm is in line with the major lobe of the antenna but there will be some advantage when a storm is in any other direction.

(*b*) *Signal-to-Noise Ratio—Effects on Television Viewing Screen*

As mentioned earlier (section entitled "Measuring Technique") we have found that the signal-to-noise ratio for the gauge point using the receiving equipment at Deal and a viewing distance of one foot is 12 decibels. This gauge point, however, may not correspond to the point where an increase in the static disturbance would necessarily be classed as objectionable when a picture is present on the television screen. The reason for this is that in the latter case the interest is centered on the picture and not upon the static as was the case during the tests we are discussing.

We have also determined the manner in which the amount of disturbance increases for smaller values of the signal-to-noise ratio when observing on a flat television field. These results are given on Fig. 8, where the lower curve shows how the number of visible disturbance crashes increases when the over-all gain is increased from its value at the gauge point. It will be seen that the average number of crashes visible at the gauge points is three per minute whereas for 12 decibels greater gain, the point where these original three crashes give full brightness, there are a total of 43 crashes per minute visible.

Not only is the total number of crashes increased when the gain is increased but the total frame area spoiled for each crash also increases. By estimation from our observations when determining the values for the lower curve and from an analysis of the wave form of lightning discharges given by Norinder[5] and others, the upper curve of Fig. 8 has been constructed. This curve represents the increase in per cent frame area spoiled as the gain is increased and at any point indicates that three crashes (the number

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[4] It should also be mentioned that points for storm distances greater than 12 to 15 miles may be in error as there was no direct method of distance measurements for these points. For close storms, distances were estimated by time measurements between lightning flashes and thunder. Beyond 10 or 12 miles this method could not be used but if lightning (night) could be seen the storm was judged to be less than 20 miles distant. In some cases neither lightning nor thunder was present in which case the storm distance was estimated from a "tapalog" recorder which was in operation during all these tests and which recorded the average static intensity at a frequency of 32 kilocycles. It is not believed that this latter method is very accurate as the correlation between actual storm distances determined during local storms and the tapalog readings was not found to be very good. This is believed to be partly due to the slow time constant of the recorder (about 10 seconds) and also to the fact that long-distance static frequently has field strengths comparable to that of the near-by storms at these low frequencies.

[5] Harold Norinder "Lightning discharges," *Jour. Frank. Inst.*, vol. 218, no. 6; December, (1934).

at the gauge point) of the total number have frame areas spoiled equal to but not much greater than the amount indicated. For example; at the gauge point three crashes per minute give a frame area spoilage of about 1/10 per cent and from the lower curve three is also the total number, while for 12 decibels greater gain three crashes per minute give a frame area spoilage of about 17 per cent and from the lower curve there are also 40 more crashes at this point which give frame area spoilage of different values between 17 per cent and zero.

This variable frame area spoilage is perhaps illustrated better by another set of curves which has been prepared from these same data and is given on Fig. 9. These curves give the number of crashes per minute, for various constant receiver-gain conditions, in which the frame area spoiled is equal to or greater than the percentage indicated. For example, the curve for a 10-decibel gain says that the total number of crashes visible which give a spoilage of 1/10 per cent or greater is 35 per minute, 25 per minute gives 1 per cent or greater, 10 per minute 5 per cent, with a maximum possible spoilage of 26 per cent.

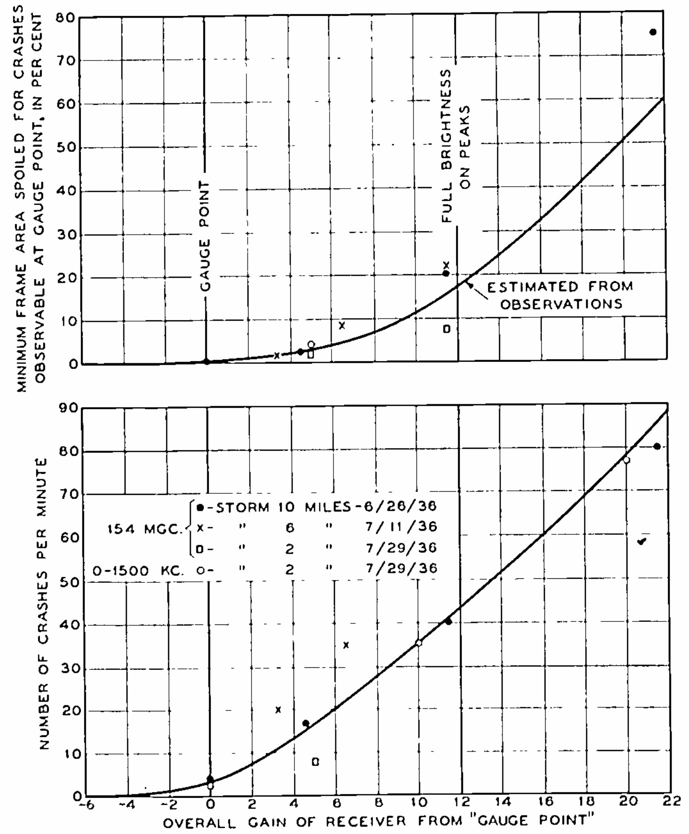

Fig. 8—Curves showing (lower curve) variation of number of visible disturbances per minute appearing on screen of cathode-ray tube as a function of receiver gain and (upper curve) per cent of cathode-ray-tube frame area spoiled as a function of receiver gain.

The interpretation of these curves when applied to television reception is not attempted here. In actual use the interference would add to or subtract from some signal carrier, then be rectified, so that on the television screen it would show part brighter and part darker than the desired picture. This fact, together with the linearity characteristics of the tube, and the absolute brightness of the field all affect the interpretation of the curves of Figs. 8 and 9.

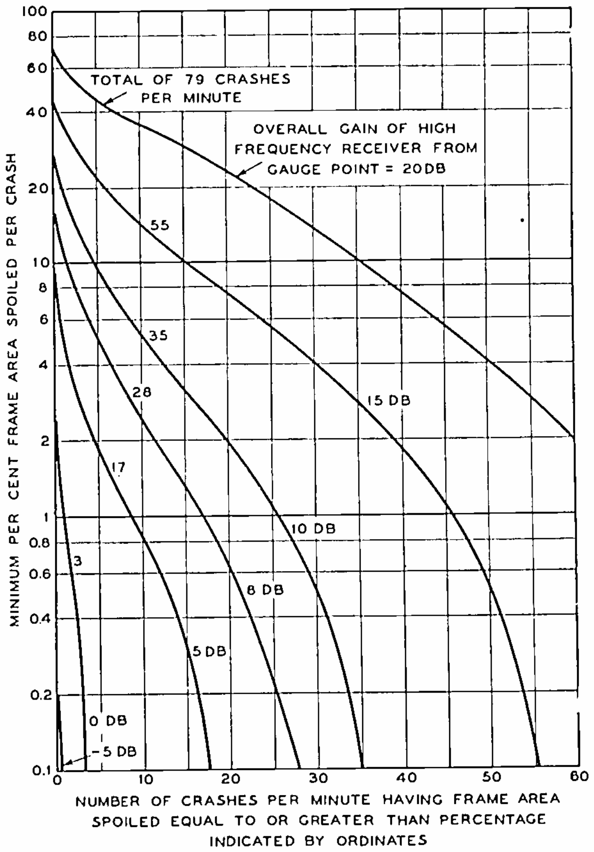

Fig. 9—Curves showing the per cent frame area spoiled per visible disturbance observed on cathode-ray-tube screen for different numbers of crashes per minute. Each curve represents a different setting of receiver gain in decibels as referred to the "gauge point."

CONCLUSIONS

The results of the experimental study described above lead to the conclusion that atmospherics due to thunderstorms will certainly cause interference to ultra-short-wave television transmission for near-by storms with signal field strengths such as might reasonably be expected. However, the amount of time during any year when such disturbances will be objectionable will be small. The decision as to whether the percentage of lost time due to thunderstorms rules out the use of any particular system can be made only when the requirements for the system under consideration are known.

An Ultra-High-Frequency Measuring Assembly*

SAMUEL SABAROFF†, NONMEMBER, I.R.E.

Summary—*A system for measuring the ultra-high frequencies is described. The general requirements of such a system are similar to those usually necessary for measurements at the lower frequencies; i.e., (1) a standard frequency source, (2) a method for generating standard harmonics and their subdivisions, and (3) a means for locating a signal with respect to these harmonics. The accuracy of the laboratory arrangement described was about one in fifty thousand at a frequency of 180 megacycles. An elaboration of this equipment should allow the accuracy of a secondary standard to be attained.*

A by-product of this investigation was a simple method for calibrating a Lecher frame, which is described in Appendix B.

PRECISION frequency-measuring assemblies for use in the range of 30 megacycles and lower have in the past been fully described.[1] It is possible by some simple equipment additions, to extend the range of these assemblies to perhaps 60 megacycles. The accuracy of measurement when using a primary standard assembly may be as high as one in five million and as high as one in five hundred thousand when using a secondary assembly.

For frequencies higher than 60 megacycles it is customary to use a Lecher frame with which an accuracy of one in twenty-five hundred may be attained.[2] Harmonics of a stable variable-frequency oscillator can also be used with an accuracy of perhaps one in ten thousand in the resulting frequency measurements.

It is evident from the foregoing that frequency-measuring methods are still in a rudimentary state insofar as frequencies above 60 megacycles are concerned. There are several reasons for this, the most important being the lack of stable oscillators for fundamental operation at these high frequencies. Many transmitters at the higher frequencies use crystal control and frequency multiplication, making it a simple matter to measure the crystal frequency and then multiply it by the harmonic number in order to find the frequency of operation. Some transmitters use a form of long-line control with a stability still under that necessitating precision measuring equipment.

Another factor is that a large majority of the transmitters operating at the high frequencies are transmitting or will transmit television or facsimile which may require a band width such that a variation of the carrier frequency of several kilocycles will have a relatively little effect on the received signal. A precision means for measuring frequency is therefore not necessary.

It is not unlikely however that as further developments are made and new uses found for the ultra-high frequencies, a precision frequency-measuring system will be necessary.

This paper is concerned with an investigation of the possibilities of making precision frequency measurements at the ultra-high frequencies. A preliminary study showed that the general requirements are identical with those of a low-frequency standard assembly; i.e., (1) a stable source of standard frequency and a means of generating the harmonics thereof, (2) a means of subdividing the intervals between these standard harmonics by means of a series of signals controlled by the standard, (3) and a method for locating the signal measured with reference to these standard controlled signals.

An oscillator, which has been described,[3] was developed for operation on the selected standard frequency of seven megacycles.

A convenient subdivision of the standard harmonic series was taken to be one megacycle. In order to be useful it was decided that this one-megacycle signal should be controlled by the standard oscillator, that is, the one-megacycle signal should be made the exact seventh submultiple of the standard seven-megacycle oscillator. The use of a multivibrator was considered for submultiplication. A search of the available literature did not reveal much definite design data on multivibrators used in the vicinity of one megacycle.

In several experimental arrangements following the same general lines as for the construction of a low-frequency multivibrator, the small interelectrode and circuital shunting capacitances which are neglected in most discussions of multivibrators were found to have a marked effect on the fundamental frequency of operation, determining to a large extent the upper frequency limit for any particular arrangement. These and other difficulties made it evident

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† Moore School of Electrical Engineering, University of Pennsylvania, Philadelphia, Pennsylvania. The work reported in this paper was carried out in the Moore School, where the author was a graduate student. The author is a transmitter engineer for the WCAU Broadcasting Company, Philadelphia. Work on this problem previously reported (PROC. I.R.E., May, (1937)), was likewise carried out in the Moore School, but through an oversight that institution was not mentioned in the paper.

[1] L. M. Hull and J. K. Clapp, "A convenient method for referring secondary frequency standards to a standard time interval," PROC. I.R.E., vol. 17, pp. 252–271; February, (1929).

[2] C. R. Englund, "The natural period of linear conductors," *Bell Sys. Tech. Jour.*, vol. 7, pp. 404–419; July, (1928).

[3] Samuel Sabaroff, "A voltage stabilized high-frequency crystal oscillator circuit," PROC. I.R.E., vol. 25, pp. 623–629; May, (1937).

that a review of the theory of the multivibrator, taking into consideration matters that would be important at the higher frequencies was desirable. This is given in Appendix A, in which the frequency of oscillation and the conditions for oscillation are determined.

Thus far we have discussed a means of generating a standard frequency and described (in Appendix A) a method for obtaining an exact submultiple of this frequency. In order to be useful it is necessary for the harmonics of the standard oscillator to cover the range in which measurements of frequency are to take place, and at will to subdivide these harmonic intervals into exact submultiples of the standard frequency. It was determined that the RCA acorn-type 954 tube was satisfactory for the purpose. A fairly intense seven-megacycle signal impressed on the grid of this tube gave a strong series of harmonics extending well above 250 megacycles. Subdividing the seven-megacycle harmonics by means of the one-megacycle submultiple could be satisfactorily accomplished by impressing the one-megacycle signal on the suppressor grid of the tube used as a harmonic generator.

The procedure indicated up till now for finding the frequency of a signal would be first to locate it within adjacent seven-megacycle harmonics and then after the one-megacycle series was inserted to locate it within the adjacent one-megacycle harmonics. Means for indicating the frequency separation between the signal being measured and an adjacent harmonic will now be described.

A rough preliminary reading of the frequency of the signal being measured is obtained by simple linear interpolation between the one-megacycle points of a calibrated dial of a simple oscillating receiver. This oscillating receiver is then tuned to the farthest adjacent one-megacycle harmonic and locked to this frequency. This is accomplished by suitable variation of the harmonic intensity and the receiver voltages. The output of the oscillating receiver or, as we shall henceforth term it, conversion detector, will be a signal having a frequency equal to the difference between the signal being measured and the harmonic by which it is controlled. The difference frequency, lying between 500 and 1000 kilocycles, is then fed into a rebuilt broadcast receiver which was accurately aligned so that it tracked to within a few kilocycles over the 500–1000-kilocycle range. Incorporated with this receiver is an accurately calibrated variable oscillator covering the same frequency range. This oscillator is made to heterodyne with the difference frequency and when tuned to zero beat gives an accurate measurement of it. An audio-frequency amplifier is connected to the conversion detector by means of an appropriate network so that a constant check on the frequency control can be had. Departure from control is evidenced by the appearance of the customary audio-frequency beat.

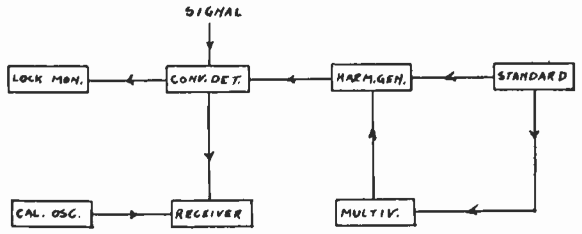

Fig. 1—Block diagram of the frequency-measuring assembly.

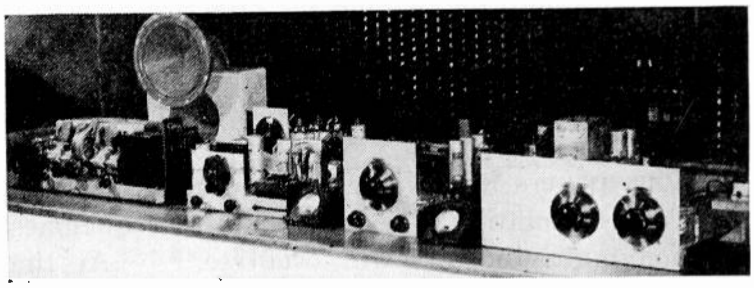

Fig. 2—General laboratory arrangement of the frequency-measuring assembly.

A block diagram of the frequency-measuring assembly is shown in Fig. 1. In Fig. 2 is shown a photograph of the laboratory arrangement.

In conclusion it must be pointed out that the setup described is merely an experimental one. The accuracy that could be expected from an elaboration of an arrangement such as this is that of a secondary standard. It will be necessary to elaborate on it considerably before the measurement of frequency can be made as simple and routine as equipment operating on the lower frequencies. With this laboratory arrangement an accuracy of about one in fifty thousand was obtained at a frequency of 180 megacycles. The instability of an oscillator operating at the ultra-high frequencies has been eliminated by means of the frequency lock between the conversion detector and a selected standard harmonic. By beating the second harmonic of the detector with an oscillator operating in the vicinity of 360 megacycles it was possible to make frequency measurements of this oscillator consistently more accurate than could be obtained by any other means.

It is possible to make this arrangement an adjunct to a primary standard assembly thus allowing considerably higher accuracy to be attained.

A by-product of this investigation was the development of a simple method for calibrating a Lecher frame as described in Appendix B.

ACKNOWLEDGMENT

The work described in this paper was done in the High Frequency Laboratory of the Moore School of Electrical Engineering.

Thanks and appreciation are due to Dr. Carl C. Chambers for his enlightening discussions and to Dr. J. G. Brainerd for reading the final drafts of this paper, both of the Moore School faculty.

APPENDIX A

Various papers have indicated methods and formulas for calculating the approximate frequencies at which multivibrators will oscillate.[4,5,6,7] At the higher frequencies, of the order of a megacycle or more, these formulas give impractical and erroneous results. The most obvious reason for this is the assumption of negligible circuital shunting and interelectrode capacitances used in their derivation.

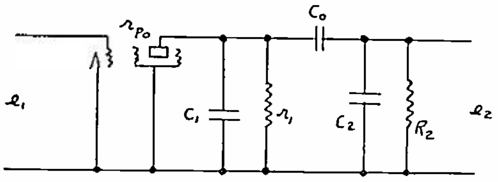

Fig. 3—Generalized diagram of a resistance-coupled stage.

It is of interest to investigate the multivibrator assuming appreciable shunting and interelectrode capacitances. It is further assumed that the tube characteristic is infinite and linear.

Consider first a simple resistance-coupled stage as outlined in Fig. 3, where r_1 and R_2 are the plate and grid resistances, C_1 and C_2 are the circuital shunting capacitances in which are incorporated the grid-to-cathode and plate-to-cathode capacitances, r_{p_0} is the internal plate resistance, μ_0 is the amplification factor, and C_0 is the coupling capacitance. It is assumed that the grid-to-plate capacitance is very small, which is approximately true for screen-grid tubes. Solving for e_2 in terms of e_1,

$$-e_2 = \frac{S_0R_0''r_{p_0}}{R_0' + \dfrac{j}{\omega C_0}(\omega^2L_0C_0 - 1)}e_1 \tag{1}$$

where,

$$\left.\begin{aligned} L_0 &= \frac{R_1R_2}{C_0}(C_1C_2 + C_0C_1 + C_0C_2) \\ R_0'' &= \frac{R_1R_2}{r_{p_0}} \\ R_0' &= R_1\left(1 + \frac{C_1}{C_0}\right) + R_2\left(1 + \frac{C_2}{C_0}\right) \\ S_0 &= \frac{\mu_0}{r_{p_0}} \\ R_1 &= \frac{r_1}{1 + \dfrac{r_1}{r_{p_0}}} \end{aligned}\right\}. \tag{2}$$

A multivibrator consists of two stages identical in appearance to Fig. (3) with the input and output of each cascaded. We can therefore write for the second stage, using double subscript notation in order to differentiate between the two stages

$$-e_1 = \frac{S_{00}R_{00}''r_{p_{00}}}{R_{00}'' + \dfrac{j}{\omega C_{00}}(\omega^2L_{00}C_{00} - 1)}e_2. \tag{3}$$

Eliminate e_1 and e_2 between (1) and (3), expand and equate imaginaries:

$$\omega^2 = \frac{R_{00}'C_{00} + R_0'C_0}{L_0C_0R_{00}'C_{00} + L_{00}C_{00}R_0'C_0}. \tag{4}$$

Equation (4) is the expression for the frequency of oscillation of the multivibrator assuming a sinusoidal wave form.

If between (1) and (3) we equate reals and insert (4) we will find that the condition for oscillation is

$$S_0S_{00} = \left[1 + \frac{(L_0C_0 - L_{00}C_{00})^2}{(R_{00}'C_{00} + R_0'C_0)(L_0C_0R_{00}'C_{00} + L_{00}C_{00}R_0'C_0)}\right] \cdot \frac{R_0'R_{00}'}{R_0''R_{00}''r_{p_0}r_{p_{00}}}. \tag{5}$$

Equations (4) and (5) give the frequency and describe the necessary conditions for oscillation in a multivibrator in which all the circuit parameters and the tube parameters are different.

In practice it is not necessary that all these values be different. It is convenient to make the two stages differ only in the value of the coupling capacitances. An approximate expression for the frequency in which first, a simplifying assumption of negligible interelectrode and circuital capacitances is made and second, a correction factor is inserted for the case in

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[4] Balth van der Pol, "The nonlinear theory of electrical oscillations," with extensive bibliography, PROC. I.R.E., vol. 22, pp. 1051–1086; September, (1934).

[5] Yasusi Watanabe, "Some remarks on the multivibrator," PROC. I.R.E., vol. 18, pp. 327–335; February, (1930).

[6] Bernard Ephraim, "Multivibrators," part 1, *Commercial Radio*, vol. 4, p. 7; July–August, (1935).

[7] V. J. Andrew, "The adjustment of the multivibrator for frequency division," PROC. I.R.E., vol. 19, pp. 1911–1917; November, (1931).

which these quantities are not negligible, can be obtained from (4); i.e.,

$$\omega^2 = \frac{1}{R_1R_2C'C''\left(1 + \frac{C''}{4C'}\right)} \tag{6}$$

where,

$$\frac{2}{C'} = \frac{1}{C_0} + \frac{1}{C_{00}}$$

$$C'' = C_1 + C_2.$$

It can be shown that to a first approximation, the grid-to-plate capacitances so far not considered, can be incorporated in (6) by adding this quantity to C''.

The circuit diagram of the multivibrator constructed from the above considerations is shown in Fig. 4. The tubes selected were RCA Type-955 tubes (3 micromicrofarads for the sum of the interelectrode capacitances). The ultra-short-wave style of construction was followed in that all leads and extraneous capacitances were minimized. C'' was estimated as approximately 15 micromicrofarads.

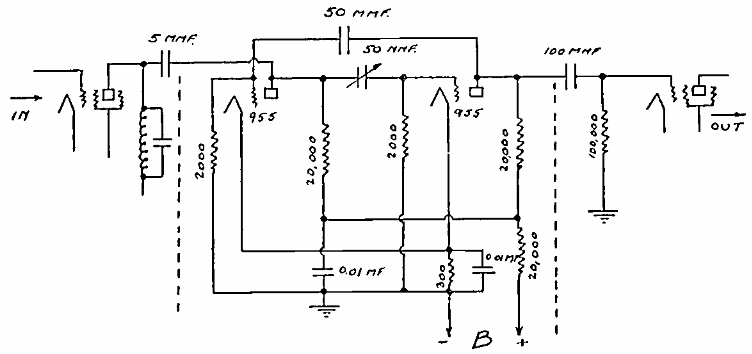

Fig. 4—Circuit of the multivibrator.

The dependable operating range of this multivibrator is 800 to 1800 kilocycles and can be used to submultiply a frequency at least ten times. It is possible to secure stable operation on both odd and even submultiples by adjusting the values of C' and the input signal intensity.

The measured and calculated fundamental frequency curves are shown in Fig. 5. It is felt that the material here presented is useful in the accurate design of multivibrators for use at the higher frequencies.

Appendix B

It can be shown that the sending-end impedance of a shorted transmission line can be expressed closely by

$$z_s = jz_0 \tan\left(2\pi \frac{s}{\lambda}\right) \tag{7}$$

where,

s = length
λ = wavelength
z_0 = characteristic impedance.

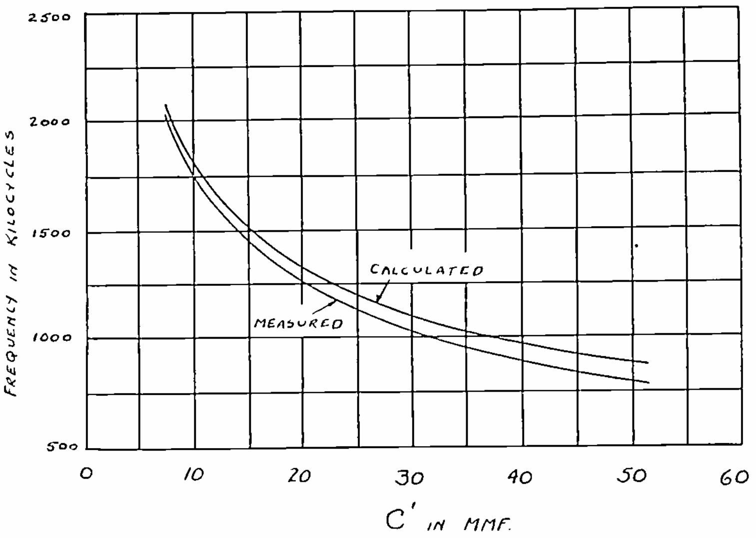

Fig. 5—Frequency of the multivibrator plotted against a variation in the equivalent coupling capacitance C'.

It is seen that z_s is a reactance and changes sign as the length of the transmission line or Lecher frame is varied through quarter wavelengths. If the receiver is tuned to produce an audible beat with a harmonic of the standard oscillator and the open end of the Lecher frame is brought in the vicinity of the tuning coil or tuning capacitance of the receiver the audible beat will vary in pitch as the length of the Lecher frame is varied since this varies the tuning of the receiver. As the length of the frame passes through even quarter wavelengths there will be a gradual rise and fall of the audible beat note but as

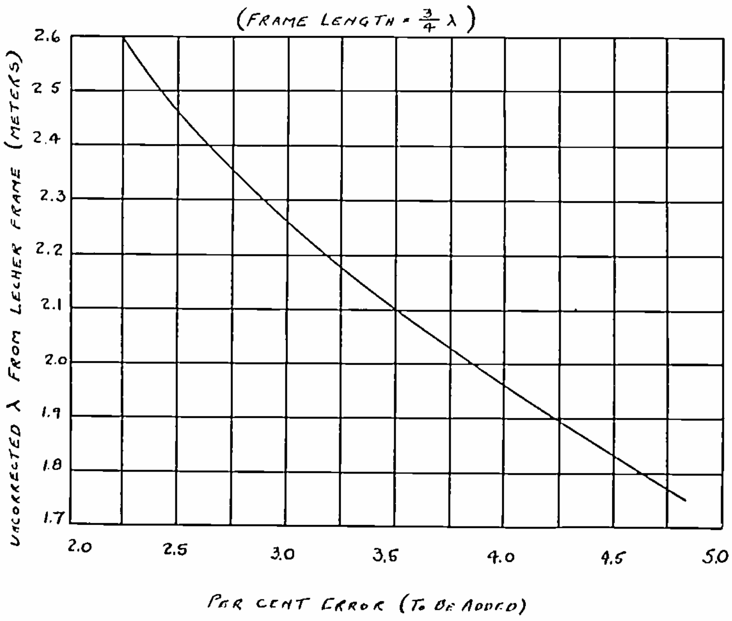

Fig. 6—Calibration curve of a Lecher frame.

the frame passes through odd quarter wavelengths there will be an apparent discontinuity in the beat note. It will gradually rise and then as the odd quarter-wave point is passed it will suddenly fall and then gradually rise again. This offers a fairly accurate means for determining the odd quarter-wavelength points.

The reason for the different way in which the odd and even quarter-wavelength points affect the receiver beat note can be explained by the fact that as the frame passes through an even quarter wavelength the sending-end impedance passes through zero in order to change sign while when the frame passes through an odd quarter wavelength the sending end impedance passes through infinity to change sign.

With the receiving end open the effect of the even and odd quarter-wavelength points, as outlined above, are interchanged.

A typical calibration curve of a Lecher frame is shown in Fig. 6. This frame was made of a pair of one-eighth-inch copper rods spaced three centimeters and one meter in length. A pair of copper tubes also one meter in length made a sliding fit over the copper rods and thus afforded a means of varying the frame length. The open end of the frame was placed about one foot from the tuning capacitances of the detector.

Control of the Effective Internal Impedance of Amplifiers by Means of Feedback*

H. F. MAYER†, ASSOCIATE MEMBER, I.R.E.

Summary—*The effective internal impedance of an amplifier may be either increased or reduced by the proper choice of one or a combination of several of the following types of feedback: 1. positive current, 2. negative current, 3. positive voltage, or 4. negative voltage.*

Impedance-reducing feedback has been applied to audio-frequency power amplifiers to flatten the response and improve the loud-speaker damping. Impedance-increasing feedback has been applied to intermediate-frequency amplifiers to increase selectivity without loss of stability.

Although a large number of papers have been published in the last few years on the subject of feedback in amplifiers, there remain some aspects of the subject which have been relatively little discussed, particularly in this country. The references on feedback are so numerous that no attempt will be made to list them all; however, since the work described below was completed, a number of papers have appeared which treat the subject from somewhat the same angle, and these will be listed later.

Feedback may be classified as positive or negative, and it may also be classified as current feedback or voltage feedback. The terms positive and negative have the commonly accepted meanings that if the voltage fed back is in phase with the input voltage, the feedback is positive; if the feed-back voltage is 180 degrees out of phase with the input voltage, the feedback is negative. In practice, the variation of phase with frequency is such that the relative phase of feedback and input is exactly 0 or 180 degrees at only one or two frequencies; however, in general it is tacitly understood that the phase somewhere near the center of the useful frequency range is the one referred to, even though it may differ by 180 degrees at another frequency outside the useful range.

The terms "current" and "voltage" feedback have not been so much used, but the names are almost self-explanatory. By voltage feedback is meant feedback of a voltage proportional to the load voltage; by current feedback is meant feedback of a voltage proportional to the load current.

The effects of these various kinds of feedback are most easily discovered by writing the equations for an amplifier containing both current and voltage feedback, each of which may be either positive or negative. Such an amplifier might theoretically be constructed as shown in Fig. 1. The tube has an amplification factor μ and a plate resistance R_p. In the plate circuit is a load Z_0. In series with Z_0 is a resistance of one ohm. Connected across the load Z_0 is a perfect transformer having a ratio $\beta:1$, and connected across the one-ohm resistance is a perfect transformer having a ratio $\alpha:1$. The secondary windings of the two transformers and the secondary winding of the input transformer are connected in series between the control grid and ground. Thus, the grid voltage consists of the sum of three voltages: the input voltage, a voltage β times the output voltage, and a voltage α times the output current. This may be expressed by

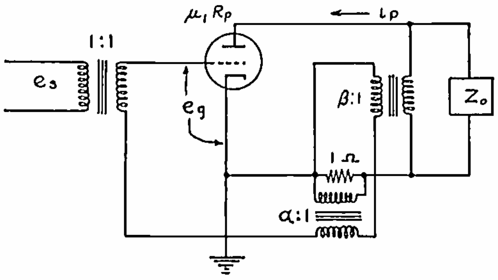

Fig. 1—General idealized feed-back circuit containing both current and voltage feedback.

$$e_g = e_s + \alpha i_p + \beta i_p Z_0$$
$$i_p(R_p + Z_0) = \mu e_g$$
$$i_p = \frac{\mu e_s}{R_p + Z_0 - \mu\alpha - \mu\beta Z_0}$$

$$e_g = e_s + \alpha i_p + \beta i_p Z_0 \tag{1}$$

where

e_g = grid voltage (volts)
e_s = signal voltage (volts)
α = current-feed-back ratio (ohms)
β = voltage-feed-back ratio (dimensionless)
i_p = plate current (amperes)
Z_0 = load impedance (ohms).

α and β may be either plus or minus. We shall call them plus if they produce positive feedback.

We may also write the usual amplifier equation

$$i_p(R_p + Z_0) = \mu e_g. \tag{2}$$

The one-ohm resistance is neglected as being small in comparison to $(R_p + Z_0)$. Combination of (1) and (2) gives

$$i_p = \frac{\mu e_s}{R_p + Z_0 - \mu\alpha - \mu\beta Z_0}. \tag{3}$$

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This equation shows the effect of either kind of feedback upon the output. For example, if α is equal to βZ_0 but of opposite sign, the output is the same as if there were no feedback present.

Let us consider now what is the effective plate resistance of the tube under feed-back conditions. This may be found by letting the signal input to the input transformer be zero, and substituting a generator for the load resistance. Then the ratio of the voltage of the generator to the current which is produced in the plate circuit will be the plate resistance as seen by the load. Fig. 2 shows the equivalent circuit from which may be written

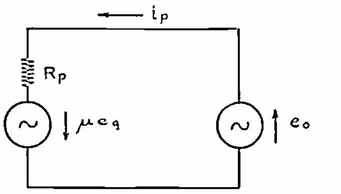


Fig. 2—Equivalent circuit for amplifier with voltage impressed at the load terminals.

$$\mu e_g + e_0 = i_p R_p$$
$$e_g = \alpha i_p - \beta e_0$$
$$R_p' = \frac{e_0}{i_p} = \frac{R_p - \mu\alpha}{1 - \mu\beta}$$

$$\mu e_g + e_0 = i_p R_p.$$

In writing the next equation it must be kept in mind that the grid voltage is defined as the sum of the signal input voltage (zero in this case), the product of the plate current by the current-feed-back ratio α, and the product of the plate voltage by the voltage-feed-back ratio, β. If there were a resistive load of R ohms in the plate circuit, the voltage feedback would be $+\beta i_p R$. However, the load resistance is zero, and the voltage e_0 which has been impressed has been assigned a polarity which is opposite to the voltage which would exist across a resistive load. Therefore the voltage feedback is $-\beta e_0$.

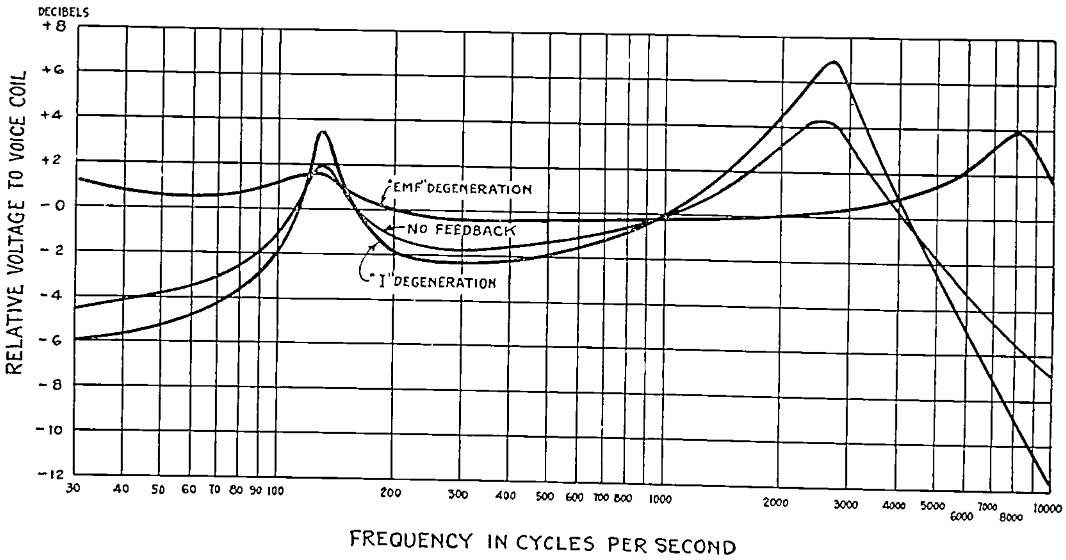


Fig 3—Amplifier voltage output to speaker load plotted against frequency, with no feedback, with negative voltage feedback, and with negative current feedback.

Then,

$$e_g = \alpha i_p - \beta e_0.$$

The effective plate resistance is

$$R_p' = \frac{e_0}{i_p} = \frac{R_p - \mu\alpha}{1 - \mu\beta}. \tag{5}$$

By letting α or β be equal to zero in (5), we may examine the effect of using either voltage or current feedback alone: If $\alpha = 0$, and β is negative, we have negative voltage feedback, which decreases the effective plate resistance in the ratio $1:(1-\mu\beta)$. If $\beta = 0$, and α is negative, we have negative current feedback, which increases the effective plate resistance in the ratio $(R_p - \mu\alpha):R_p$. The curves in Fig. 3 illustrate the effects of these two types of feedback in a power amplifier driving a loud speaker. Voice-coil voltage is plotted against frequency, with constant-voltage signal input. The value of α used in the current-feed-back case was equal to the value of βZ_0 used in the voltage-feed-back case, at a frequency of 1000 cycles.

Equation (5) suggests some other possibilities immediately. Suppose we let $\mu\alpha = R_p$; then the effective plate resistance is zero. If at the same time $\mu\alpha = -\mu\beta Z_0$, the output of the amplifier is the same as it would be with no feedback. This should make a good audio-frequency power amplifier, from the standpoint of frequency characteristic and loud-speaker damping. That it does what it should is shown by the curves in Fig. 4, and the oscillograms in Fig. 5. The oscillograms were taken on a cathode-ray oscillograph by connecting the vertical deflection plates to the voice coil, to indicate generated voltage, and using a linear sweep on the horizontal deflection plates. The speaker cone was struck mechanically at the start of each sweep, the striker and the sweep being synchronized by the 60-cycle line voltage. Actual bridge measurements of the impedance of the tube as seen by the load checked closely the predicted values.

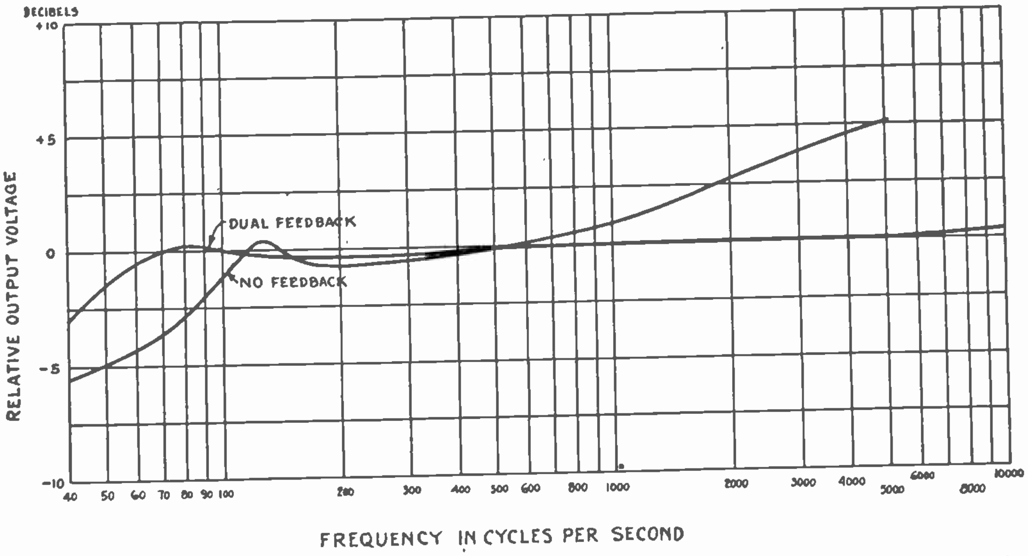
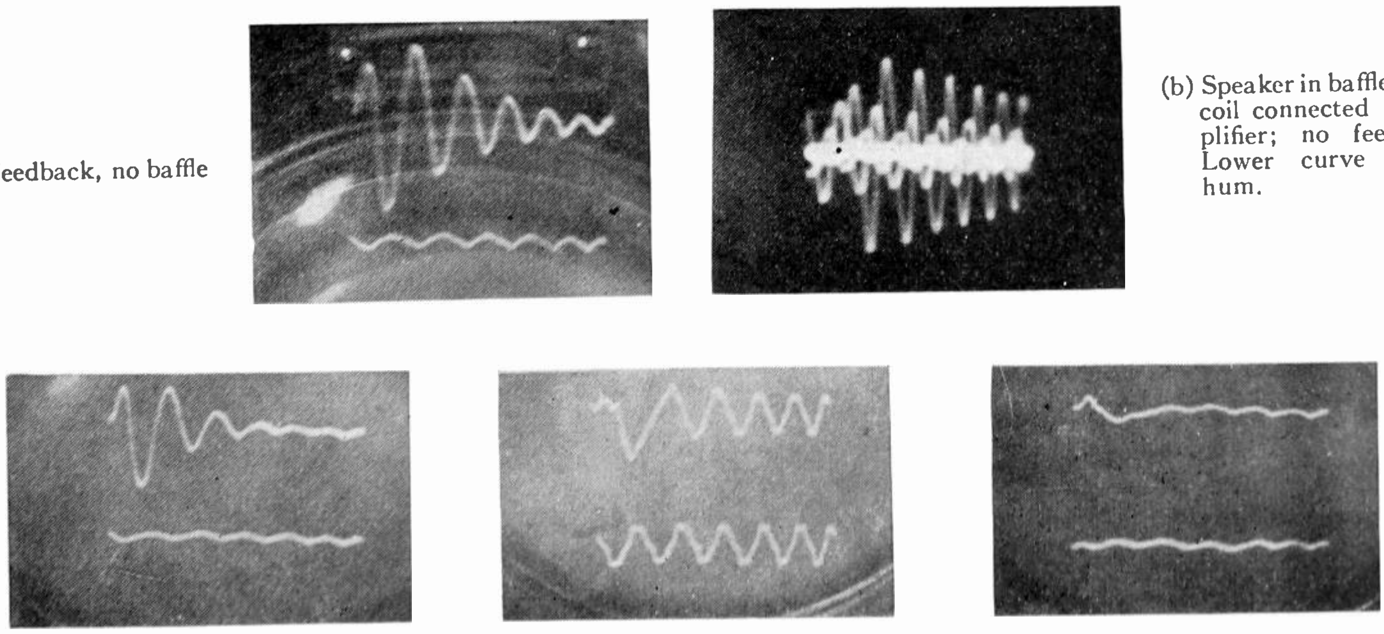


Fig. 4—Amplifier output to speaker load, plotted against frequency, with no feedback and with dual feedback.



(a) No feedback, no baffle

(b) Speaker in baffle, voice coil connected to amplifier; no feedback. Lower curve shows hum.

(c) Negative voltage feedback

(d) Positive current feedback.

(e) Dual feedback.

Fig. 5—Oscillograms showing speaker damping by feedback.

Fig. 6 shows a practical circuit for obtaining the proper polarities of α and β. The voltage feedback is negative and is obtained simply from a voltage divider across the load. The current feedback is positive, and while it can be obtained in the proper polarity by means of a phase-reversing transformer as shown in Fig. 1, it requires a very good transformer to give good results over the whole audio-frequency range. In the circuit shown, the necessary phase reversal is obtained by feeding back to the input of the previous stage.

Referring to (5), it may be seen that if $\mu\alpha$ is positive and numerically greater than R_p, and $(1-\mu\beta)$ is positive, the effective plate resistance is negative. Fig. 7 illustrates such a case. Curve A shows the voice-coil voltage versus frequency of a loud speaker driven by a pentode with no feedback. Curve B is with negative voltage feedback only and shows decreased plate resistance, as indicated by the flattening of the curve. Curve C is with positive current feedback only, of such an amount that at 1000 cycles $\alpha=\beta Z_0$. $\mu\alpha$ is greater than R_p, and negative, and R_p'' is therefore negative, as is borne out by the inversion of the curve. Now when both feedbacks are applied at once, as in curve D, the effective plate resistance becomes numerically smaller, but remains negative. Curves A and D have the same ordinate scale and give equal outputs at 1000 cycles. Curve B with negative feedback has been multiplied by a factor to bring it up to the same level as A at 1000 cycles, and curve C has been divided by a factor to bring it down to A at 1000 cycles.

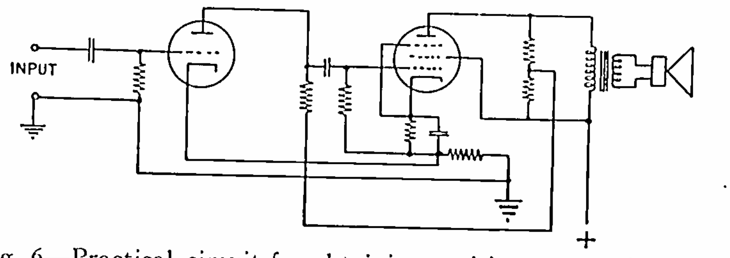


Fig. 6—Practical circuit for obtaining positive current feedback and negative voltage feedback in an audio-frequency amplifier.

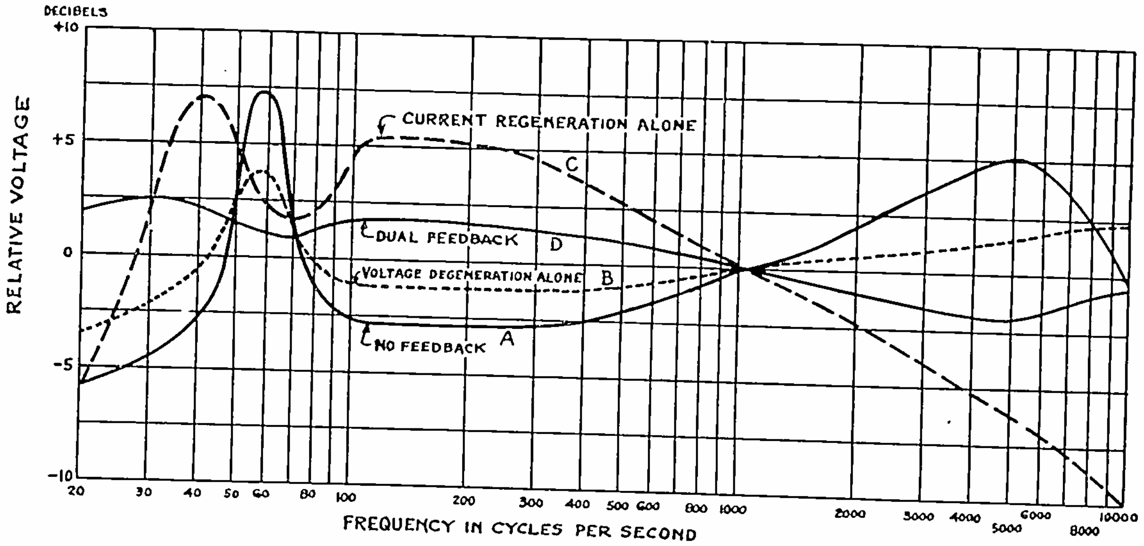


Fig. 7—Effects of various combinations of feedback upon the frequency characteristic of an audio-frequency amplifier driving a speaker.

A study of (5) leads to the following generalizations:

1. Negative voltage feedback or positive current feedback decreases plate resistance.
2. Negative current feedback or positive voltage feedback increases plate resistance.

Obviously, almost by definition, positive feedback increases gain and negative feedback decreases it. It is well known that negative feedback decreases harmonic distortion in the same ratio as it decreases gain. The same reasoning which demonstrates this point will show that positive feedback increases distortion, and that any combination of feedback changes the distortion by the same amount as it changes the gain. This fact prevents the combination of positive current feedback and negative voltage feedback, to give very low plate resistance, from being as useful as it might otherwise be, since the harmonic reduction ordinarily is more important than the loss of gain encountered with only negative feedback.

Again considering (5), it may be observed that if $\mu\beta=1$, R_p is infinite. This suggests that the damping effect of the plate resistance of a tube upon a tuned circuit load might be removed by feedback. The simplest way to obtain this with a tuned plate load is in the manner shown in Fig. 8; a feed-back coil of the proper number of turns, in series with the cathode, is coupled to the plate-circuit coil. This circuit may be recognized as a common one for oscillators and regenerative detectors, and the increase in selectivity afforded by a properly adjusted stage of regenerative amplification is well known. In practice, the effective plate resistance is increased not only to infinity, but even beyond; that is, it is made negative. The effect of the negative plate resistance is to neutralize some of the positive resistance in the load. If R_p' is made numerically equal to the load resistance, but negative, then the net resistance is zero, and oscillation occurs. As R_p' is made to ap-

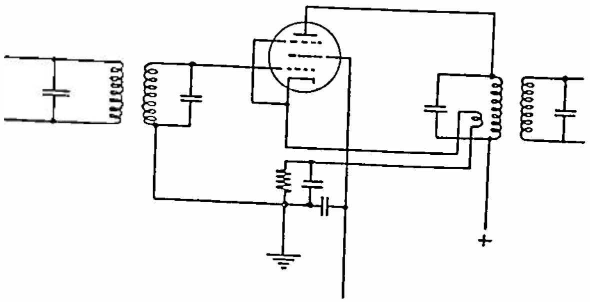


Fig. 8—Positive voltage feedback applied to an intermediate-frequency amplifier.

proach the numerical value of the load resistance, with a negative sign, the selectivity increases without limit. However, from the standpoint of stability, the use of simple regeneration as a means of increasing selectivity is unsatisfactory. As an example, consider a tube with a plate resistance R_p and a load resistance also R_p. With positive voltage feedback, oscillation will occur at $\mu\beta = +2$. Let us stop short of oscillation so that $R_p' = -1.2R_p$, in which case $\mu\beta = 1.833$. At this point an increase in μ of 10 per cent is sufficient to permit oscillation. Now let us consider the same tube and same load, and introduce first a negative current feedback of $\mu\alpha = -2R_p$, as before. Now $\mu\beta$ must be 3.5, and we find that a 10 per cent increase in μ will make R_p' only -1.12, and that a 33 per cent increase in μ is necessary to cause oscillation. The stability has been improved at the cost of some of the amplification, since degenerative current feedback has been added to counteract some of the regenerative voltage feedback. Negative current feedback is easily obtained by omitting the by-pass condenser from the usual self-bias resistor. The amount of current feedback obtainable may be increased by the circuit shown in Fig. 9, where only a part of the cathode resistor supplies bias, but all of it supplies feed-back voltage.

If the impedance of the grid-cathode capacitance is not large compared to the grid-circuit impedance, the phase and magnitude of the feed-back voltages will be somewhat different from the expected values, and this fact prevents the circuit from operating correctly at high frequencies. Even at intermediate frequencies, this effect is appreciable, but with moderate amounts of feedback, the errors are not noticeable. This unfortunate presence of tube capacitances prevents a beautiful phenomenon from being widely applicable. If both the negative current feedback and the positive voltage feedback are made very large, and $\mu\alpha$ is kept numerically equal to $\mu\beta R_0$ (where R_0 is the resonant impedance of Z_0), the effective plate resistance approaches $(-R_0)$ as a limit; in other words, it not only approaches the value at which the net circuit resistance is zero, and the selectivity infinite, but it becomes independent of both μ and R_p. An application which would take advantage of this remarkable circumstance would have to be at a very low frequency in order to avoid the effects of the unwanted capacitances.

As for practical results, the application of this circuit to an intermediate-frequency amplifier stage having an adjacent-channel attenuation of about 15 brought it up to 55. There was practically no change in the resonance curve when the line voltage was varied over a range of nearly 2:1, and the gain changed no more than it did when no feedback was present.

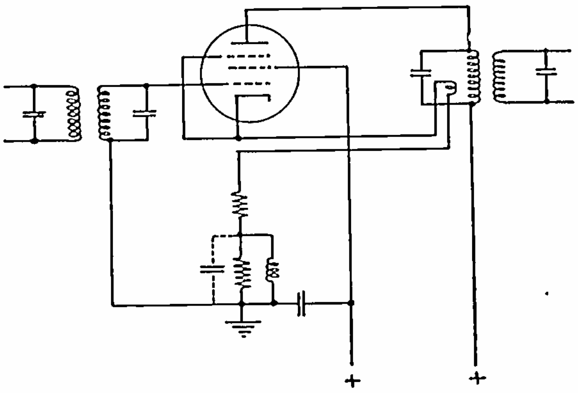


Fig. 9—Positive voltage feedback and negative current feedback applied to an intermediate-frequency amplifier.

Applying some figures to the case discussed above, where the effective plate resistance was to be made -1.2 times the actual plate resistance, let us consider a tube with a μ of 1500 and a plate resistance of one megohm. The voltage-feed-back coil necessary to give the desired amount of feedback will be found to have approximately one per cent as many turns as the plate coil. To make $\mu\alpha = -2R_p$, $\alpha = 1333$ ohms.

CONCLUSION

It has been shown that the effective plate resistance of an amplifier tube may be decreased by the use of either positive-current feedback or negative voltage feedback or both. This is applicable to audio-frequency amplifiers. The effective plate resistance may be increased by the use of positive voltage feedback or negative current feedback or both. This is applicable to intermediate-frequency amplifiers or audio-frequency amplifiers where a sharp, narrow band-pass is desired.

References

The only published record of experimental work along this line is by F. Vecchiacchi, who published a paper entitled "Negative resistance and high selectivity obtained stably by means of positive and negative feedback," in *Alta Frequenza*, vol. 6, pp. 351–364; June, (1937). He describes only one experiment; namely, one similar to the high-frequency application discussed above, except that he uses the tube only to increase the effective Q of a tuned circuit, and not as an amplifier. Furthermore, his experiment was performed at a frequency of only 5000 cycles. This made the harmful effect of the interelectrode capacitances so small that he was able to obtain a stable increase in Q of 100 times.

H. Bartels, *Elek. Nach. Tech.*, vol. 9, pp. 319–329; September, (1934) gives a very complete theoretical presentation of current and voltage feedback used in combination, to obtain a desired effective plate resistance. However, he seems to have attempted no practical application of his ideas.

E. L. Ginzton "Balanced feed-back amplifiers," PROC. I.R.E., vol. 26, pp. 1367–1379; November, (1938), describes the simultaneous use of positive and negative feedback in an audio-frequency amplifier for the purpose of improving the frequency characteristic. A circuit somewhat similar to the audio-frequency circuit discussed in the first part of this paper was described.

Some Dynamic Measurements of Electronic Motion in Multigrid Valves[*]

M. J. O. STRUTT[†], NONMEMBER, I.R.E., AND A. VAN DER ZIEL[†], NONMEMBER, I.R.E.

Summary—*Recently developed means for measuring tube admittances on short waves are described in a general way in the introduction. Admittances, which are chiefly dealt with, are the input admittance between the input grid and the cathode and the complex transconductance between the input grid and the anode. In section II a pentode, consisting of a cathode, grid 1, grid 2, grid 3, and an anode is considered. Grid 1 is negative, grid 2 positive, grid 3 either negative or positive, and the anode positive. The probability of an electron, arriving before grid 3, to pass through grid 3 is called α and the probability that an electron, which is returned before grid 3, arrives a second time before grid 3 is called β. Input grid admittance is calculated in terms of α and β, two expressions being obtained, one being the additional input damping due to electrons returning before grid 3 and the other being the additional input capacitance due to the same cause. Measurements of these quantities for pentodes, hexodes, heptodes, and octodes are described in section III, whereas α and β are calculated from these measurements in section IV, several checks being obtained. In section V formulas for the influence of returning electrons on complex transconductance are derived and applied to measurements in section VI.*

I. Introduction

ELECTRONIC motions in multigrid valves, e.g., tetrodes, pentodes, hexodes, heptodes, and octodes, while in use as amplifiers or frequency changers, are rather complicated. A complete knowledge of these motions would lay the foundation for further improvements of their construction. New means for obtaining this knowledge have been found in admittance measurements on ultra-short waves. Recently these measurements have been made considerably more accurate and easier by the use of elaborately screened apparatus.[1–7] We are here chiefly concerned with admittance measurements between a negative grid and the cathode and with admittance (transconductance) from a negative grid to a positive electrode.

The admittance between a negative grid and the cathode is measured as follows: A tuned circuit with a variable condenser of known calibration curve is loosely coupled to a transmitter. The induced electromotive force is constant and independent of the tuning position of the variable condenser. It can be shown that the alternating voltage, measured across the circuit by means of a diode voltmeter, using an acorn diode, is proportional to the absolute value of the circuit impedance at each position of the tuning condenser. By measuring this alternating voltage as a function of the condenser tuning position, a resonance curve is obtained. From this resonance curve, the condenser scale being calibrated, the admittance value of the circuit for the frequency under consideration may be derived. By measuring this admittance without and with the tube admittance parallel to it, the tube admittance is obtained. This procedure has been applied successfully to the input and to the output admittance of valves up to frequencies of about 300 megacycles.

A different method was applied for measuring the transconductance (slope) from one valve electrode to another. This transconductance is complex at the short waves under consideration. It has been compensated by a known complex admittance, the circuit being an extension and elaboration for short waves of the well-known compensation method for the measurement of tube transconductance at low frequencies. Measurements up to 40 megacycles have been successfully taken in this way.

In order to derive the electronic motion in multigrid valves from admittance measurements of this type a number of formulas have to be established and we accordingly proceed with their derivation.

II. The Influence of Returning Electrons in Multigrid Valves on Input Admittance

The simplest valve, in which returning electrons may have a pronounced influence on input admittance is a tetrode. We take the static tensions for the input grid to be fixed and negative, for the screen to be fixed and positive, and for the anode to be negative or positive with respect to the cathode. Secondary

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[†] Natuurkundig Laboratorium der N. V. Philips' Gloeilampenfabrieken, Eindhoven, Holland.

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[4] M. J. O. Strutt, "Characteristic constants of h. f. pentodes. Measurements between 1,5 and 300 Mc/s.," *Wireless Eng.*, vol. 14, pp. 478–488; September, 1937.

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[6] W. R. Ferris, "Input resistance of vacuum tubes as ultra-high-frequency amplifiers," Proc. I.R.E., vol. 24, pp. 82–107; January, (1936).

[7] F. B. Llewellyn, "Phase angle of vacuum tube transconductance at very high frequencies," Proc. I.R.E., vol. 22, pp. 947–956; August, (1934).

emission is neglected temporarily. Then, if the anode is made negative, the electrons that have passed the screen a first time will be returned in the screen-anode space and, passing the screen a second time, will arrive again in the vicinity of the input grid. By their presence in the space between the input grid and the screen the electrons will influence charges on the input grid and thus cause an alteration of the admittance between the input grid and the cathode. This alteration will be calculated.

In order to obtain formulas, which may be easily applied to hexodes, heptodes, and octodes, a pentode valve will be considered instead of the tetrode mentioned above. For a pentode, secondary emission of the anode is, in the cases considered here, without effect. The grids will be numbered starting from the cathode, the input grid being grid 1, the screen grid 2, and the suppressor grid 3.

We consider an electron, which arrives before grid 3, after passing through grid 2. The probability, that this electron passes through grid 3 is called α. Hence the probability that it is returned in the direction of grid 2 is $1-\alpha$. An electron, which has thus been returned may land on grid 2, which is positive. It may also pass grid 2 and arrive in the vicinity of grid 1 or of the cathode. Here it may dive into the space-charge cloud surrounding the cathode and is then indistinguishable from freshly emitted electrons. If it survives these possibilities, it is attracted in the direction of grid 2 and if it passes again through grid 2, it lands a second time before grid 3. The probability of an electron, returning before grid 3 in the direction of grid 2, to arrive a second time before grid 3 is called β (of course $\beta \leqq 1$). If we know α and β for a set of voltages on the tube electrodes, the electronic motion for these voltages may be accurately described. We proceed to derive a relation of these fundamental quantities α and β with the admittance between grid 1 and the cathode.

In our calculations we make use of the well-known complex notation. Let the alternating voltage between grid 1 and the cathode be represented by $E \exp(j\omega t)$, where E is the voltage amplitude, ω equal to 2π times the frequency in cycles, t is the time in seconds, and $j=+\sqrt{-1}$. The alternating electronic current, composed of electrons, which have traveled the way from grid 1 to grid 2 only once, on arriving before grid 2, is equal to $S_k E \exp(j\omega t - j\phi_l)$, where S_k is the absolute value of the transconductance from grid 1 to the positive tube electrodes. The phase angle ϕ was shown theoretically and experimentally[3] to be equal to $\phi=\phi_l+\omega\,(0.36t_{kg1}+t_1/2)$, where t_{kg1} is the electron transit-time from the cathode to grid 1, t_1 is twice the electron transit-time from grid 1 to grid 2, and ϕ_l is the phase angle due to the tube leads. This alternating electronic current passes partly through grid 2, travels from grid 2 to grid 3, is partly returned to grid 2, again passes partly through grid 2 and arrives in the vicinity of grid 1. The alternating electronic current thus arriving in the vicinity of grid 1 is given by $S_k E\beta(1-\alpha) \exp(j\omega t - j\phi_l - j\omega 0.36 t_{kg1} - j\omega t_1 - j\omega t_2)$, where t_2 is twice the electron transit-time from grid 2 to grid 3. This process is repeated and the resulting alternating electronic current, arriving in the neighborhood of grid 1 from the side of grid 2 becomes

$$\begin{aligned}
&S_k E\beta(1-\alpha) \exp(\phi_0 - j\omega t_1 - j\omega t_2)\\
&+S_k E\beta^2(1-\alpha)^2 \exp(\phi_0 - j\omega 2t_1 - j\omega 2t_2)\\
&+S_k E\beta^3(1-\alpha)^3 \exp(\phi_0 - j\omega 3t_1 - j\omega 3t_2)\\
&+\cdot\;\cdot\;\cdot\;\cdot\;\cdot\;\cdot\;\cdot\;\cdot\;\cdot\;\cdot\;\cdot\;\cdot\;\cdot\;\cdot\;\cdot\;\cdot\;\cdot\\
&=S_k E\beta(1-\alpha) \exp(\phi_0 - j\omega t_1 - j\omega t_2)\\
&\times \sum_{n=0}^{\infty} \beta^n (1-\alpha)^n \exp\left[-j\omega n(t_1+t_2)\right]\\
&=S_k E\beta(1-\alpha) \exp(\phi_0 - j\omega t_1 - j\omega t_2)\\
&\times\frac{1-\beta(1-\alpha)\cos\omega(t_1+t_2) - j\beta(1-\alpha)\sin\omega(t_1+t_2)}{1-2\beta(1-\alpha)\cos\omega(t_1+t_2)+\beta^2(1-\alpha)^2}. \qquad (1)
\end{aligned}$$

In these equations ϕ_0 stands for

$$j\omega t - j\phi_l - j\omega 0.36 t_{kg1}.$$

The summation may be checked by using any compendium on infinite series. We may choose the angular frequency ω such, that $\omega(t_1+t_2) \ll 1$ and hence $\cos\omega(t_1+t_2)=1$ and $\sin\omega(t_1+t_2)=\omega(t_1+t_2)$. Inserting these values and neglecting $0.36t_{kg1}$, against t_1 and t_2, (1) yields

$$\begin{aligned}
I &= S_k E\beta(1-\alpha) \exp(j\omega t - j\phi_l - j\omega t_1 - j\omega t_2)\\
&= \frac{1-\beta(1-\alpha) - j\beta(1-\alpha)\omega(t_1+t_2)}{\{1-\beta(1-\alpha)\}^2}. \qquad (2)
\end{aligned}$$

By this electronic current an alternating current is induced upon grid 1. This was shown to be[8,9]

$$\tfrac{2}{3} j\omega t_1 I. \qquad (3)$$

Dividing (3) by the voltage $E \exp(j\omega t)$ yields the admittance Y_1 between grid 1 and the cathode,

$$\begin{aligned}
Y_1 &= \tfrac{2}{3} S_k \beta(1-\alpha) j\omega t_1 \{1 - j\omega(t_1+t_2)\}\\
&\times \frac{1-\beta(1-\alpha) - j\omega\beta(1-\alpha)(t_1+t_2)}{\{1-\beta(1-\alpha)\}^2}. \qquad (4)
\end{aligned}$$

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[8] C. J. Bakker and G. de Vries, "Amplification of small alternating tensions by an inductive action of the electrons in a radio valve with negative anode," *Physica*, vol. 1, pp. 1045–1054; November, (1934).

[9] W. A. Harris, "The application of superheterodyne frequency conversion systems to multirange receivers," Proc. I.R.E., vol. 23, pp. 279–294; April, (1935).

In this step, ϕ_l has been neglected, as compared with $\omega(t_1+t_2)$, which, by previous measurements, has been shown to be justified.[3] The admittance Y_1 may be separated in a real and an imaginary part

$$Y_1 = \frac{1}{R} + j\omega C. \tag{5}$$

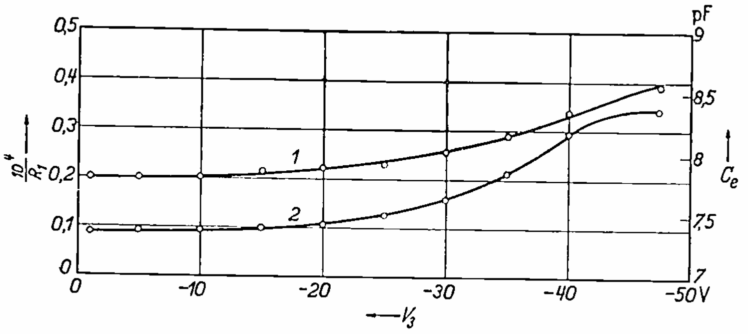

Fig. 1—Input capacitance C_e in micromicrofarads (curve 1) and reciprocal input resistance $1/R_1$ (curve 2) as a function of the negative voltage on the suppressor grid (horizontal) of a pentode valve type AF3 (Philips) measured at a wave length of 22.7 meters.

Equating (5) to (4), we find

$$C = \frac{2}{3} S_k \frac{\beta(1-\alpha)}{1-\beta(1-\alpha)} t_1 \tag{6}$$

$$\frac{1}{R} = \frac{2}{3} \omega^2 t_1(t_1+t_2) \frac{S_k\beta(1-\alpha)}{\{1-\beta(1-\alpha)\}^2}. \tag{7}$$

At this point, several assumptions, introduced tacitly or otherwise in the derivation of (6) and (7), will be listed. The action of space charge between grid 1 and grid 2 has been neglected, as the induction of an alternating current to grid 1 by the returning electronic current was calculated by simple summation of the actions, due to the single electrons.[8] The mean path of an electron, returning from grid 3 through grid 2 is assumed to lead to the immediate neighborhood of grid 1. Also the returning point between grid 2 and grid 3 is assumed to lie close to grid 3 as a mean value for all returning electrons. Electrons, which have passed through grid 3 are assumed not to return. The transconductance, which has to be inserted into (2) will probably be somewhat smaller than S_k. While some of these assumptions carry an arbitrary element, their justification must be sought in the successful application of the resulting equations (6) and (7) to several measurements, which is shown in section IV.

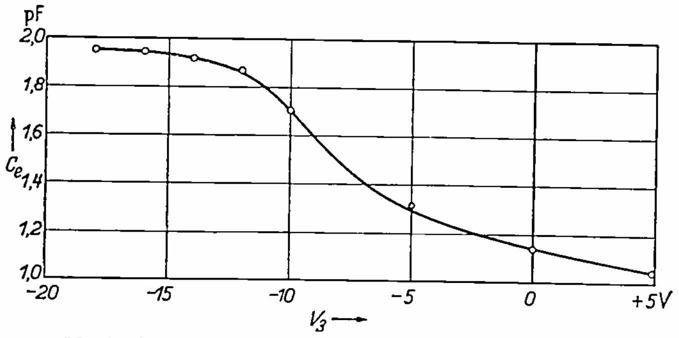

Fig. 2—Variation of input capacitance of heptode EH2 (somewhat similar to the 6L7) (vertical scale, micromicrofarads) as a function of the bias on grid 3 (from the cathode) in volts. A constant capacitance has to be added to the C_e values to obtain the input capacitance. Voltages were: grid 1 at 2 volts, grids 2 and 4 each 70 volts, anode 200 volts. Wavelength 14.4 meters.

III. MEASUREMENTS OF INPUT ADMITTANCE OF PENTODES, HEPTODES, AND OCTODES

A high-frequency pentode type AF3 (Philips) was used with 250 volts on the anode, 100 volts on the screen, and −3 volts on grid 1. Input admittance was measured as a function of the tension on grid 3 (see Fig. 1) at a wavelength of 22.7 meters. A large variation of this input admittance, due to returning electrons, is observed.

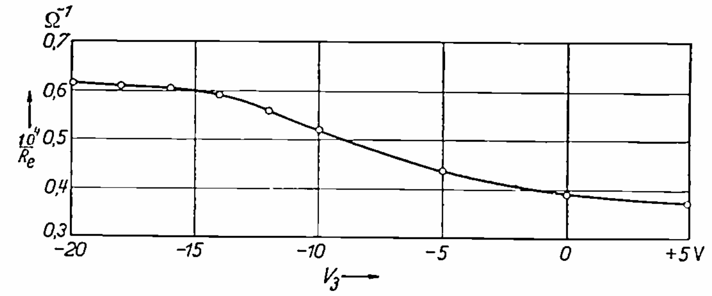

Fig. 3—Variation of input conductivity of tube EH2 (vertical) against bias volts on grid 3 (horizontal) under same conditions as for Fig. 2. Wavelength 14.4 meters.

Whereas this mode of operation is uncommon for a pentode tube, an analogous operation is quite regular with hexode and heptode tubes, used as mixers or as amplifiers. An example of such a tube is the 6L7. A European tube of similar construction, with different grid dimensions, is the EH2 (Philips). In this tube the third grid (from the cathode) is usually negatively biased. The input admittance of this tube is shown in Figs. 2 and 3 at a wavelength of 14.4

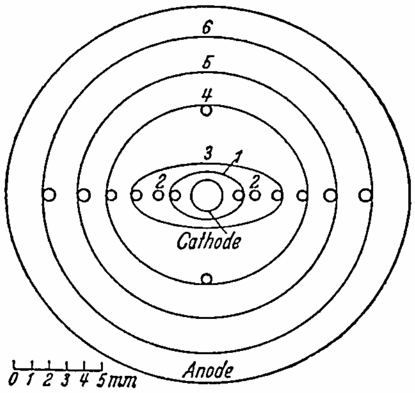

Fig. 4—Cross section to scale of octode type AK2 (Philips) electrode constellation. This is a mixer valve somewhat resembling the 6A8, but with an added suppressor grid (grid 6) in order to enhance the internal output resistance.

meters. Here again, a large variation of input admittance with bias voltage on grid 3 is observed.

A cross section of the electrode construction of an octode valve, type AK2, is shown in Fig. 4 to scale. The currents to different electrodes as a function of the bias voltage on grid 4 (see Fig. 4) are shown in Fig. 5. It is seen from this Fig. 5 that the electrons returning before grid 4 mostly go to the rods 2. If the rods are connected to the cathode, they land on grid 3. The current, which passes through grid 4 is little influenced by the voltage of the rods 2. The variation of the capacitance measured between grid 1 and the cathode as a function of the bias on grid 4 is shown in Fig. 6. The variation of the resistance measured between grid 1 and cathode is seen from Fig. 7 at a wavelength of 16.1 meters. Whereas the capacitive variations are independent of the wavelength down to less than 4 meters, the resistance variations are materially influenced by the wavelength as may be seen from (6) and (7). The curves of Figs. 6 and 7 show irregularities at points, corresponding to a bias of about −2 volts on grid 4. If we neglect these irregularities in Figs. 6 and 7, all the measurements of Figs. 1, 2, 3, 6, and 7 show similar trends. The values of the capacitance and the conductivity are constant for greatly negative bias values and become constant again if the bias is made sufficiently positive.

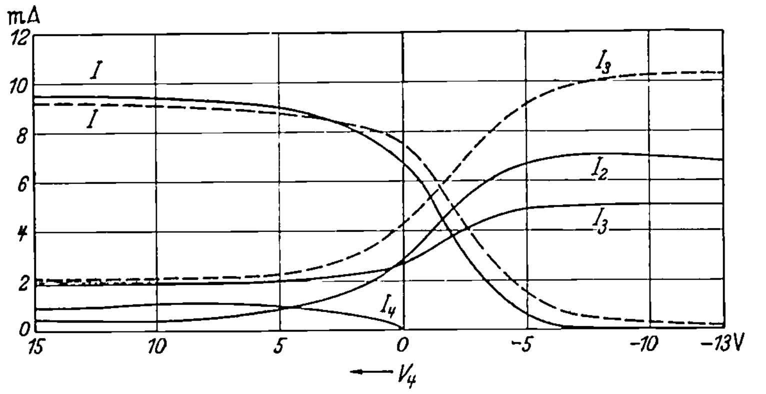

Fig. 5—Currents to the different electrodes of Fig. 4. (vertical, milliamperes) against bias (volts) on grid 4 (horizontal). For the full curves voltages are: anode 70 volts, grid 6 connected to the cathode, grids 3 and 5 each 70, rods 2 each 90 volts. For the dashed curves we have: anode, grid 5, grid 3 each 70 volts, rods 2 and grid 6 connected to cathode. I is the current to the anode and to grid 5, I_3 the current to grid 3, I_2 the current to the rods 2, and I_4, the current to grid 4. The full and dotted curves of I_4 coincide.

IV. Calculations of Electronic Motion from the Measurements of Section III

In the case of the pentode AF3, α is the probability for an electron arriving before grid 3, after passing through grid 2, to land on the anode, and $1-\alpha$ is the probability to return in the direction of grid 2. Of these returning electrons the fraction β arrives a second time before grid 3. We assume that β does not depend on the bias of grid 3. This is a first approximation, which will be later shown in the case of the EH2, to be rather near the truth. If all electrons are returned before grid 3 (large negative bias) we have $\alpha=0$ and if all electrons are passed by grid 3 (positive bias), $\alpha=1$. In this latter case (6) and (7) yield zero, as no electrons are returned. We take $\alpha=0$ in these equations and find

$$C = \frac{2}{3} 3S_k \frac{\beta}{1-\beta} t_1 \tag{6a}$$

$$\frac{1}{R} = \frac{2}{3}\omega^2 t_1(t_1+t_2)S_k\beta\{1-\beta\}^{-2}. \tag{7a}$$

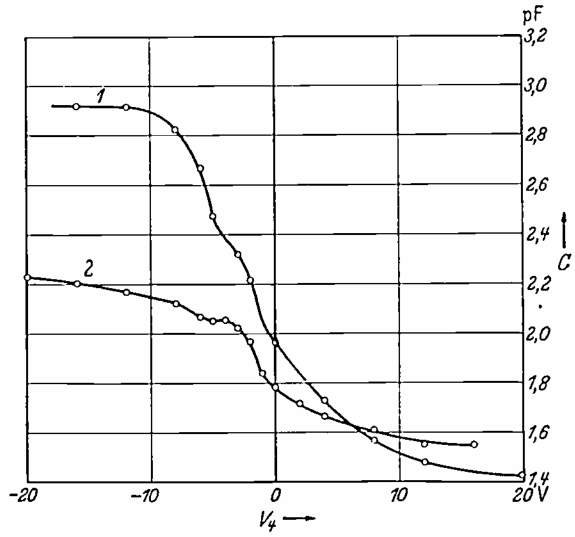

Fig. 6—Capacitance variation, measured between grid 1 and cathode of octode valve $AK2$ (vertical, micromicrofarads), against bias volts on grid 4 (horizontal). Curve 1: tension on anode, grid 5 and grid 3 each 70 volts, grids 6 and 2 connected to cathode. Curve 2: anode, grid 5, grid 3 and grid 6 as with curve 1 but rods 2 each 90 volts. Wavelength 16.1 meters.

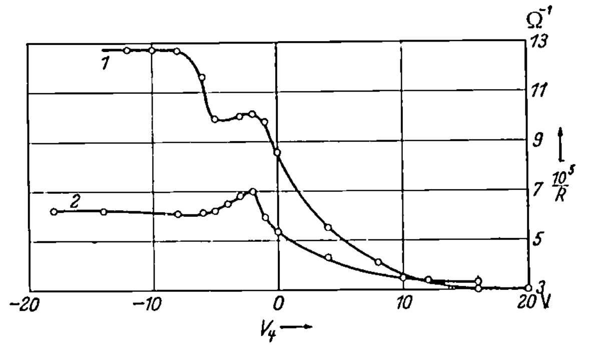

Fig. 7—Variation of conductivity $1/R$, measured between grid 1 and cathode against bias on grid 4. Voltages for curves marked 1 and 2 are equal to those for the corresponding curves of Fig. 6. Wavelength 16.1 meters.

We first deal with the pentode AF3. The transit-times t_1 and t_2 may be calculated from the grid distances. The distance from grid 1 to grid 2 is 0.10 centimeter and the distance from grid 2 to grid 3 is 0.25 centimeter. The mean electron velocity on the grid 1 to grid 2 path as well as on the grid 2 to grid 3 path is $0.5 \cdot 5.93 \cdot 10^7 (V_2)^{1/2}$ cm sec^{-1}, where V_2 is the potential of grid 2. Hence $t_1 = 0.67 \cdot 10^{-9}$ second and $t_2 = 1.69 \cdot 10^{-9}$ second. The transconductance S_k is $2.0 \cdot 10^{-3}$ ampere per volt with this tube and $\omega = 0.83 \cdot 10^8$ (22.7 meters wavelength). Hence,

$$\tfrac{2}{3}\omega^2 S_k t_1(t_1 + t_2) = 1.46 \cdot 10^{-5} \quad \text{and}$$

$$\tfrac{2}{3} S_k t_1 = 0.90 \cdot 10^{-12}.$$

The values of C and $1/R$ may be taken from Fig 1. At $V_3 = -50$ volts in this figure practically no electrons are passed by grid 3 ($\alpha = 0$), whereas at $V_3 = 0\,V$ practically all electrons are passed ($\alpha = 1$). The difference between these two extreme points yields $1/R = 0.26 \cdot 10^{-4}$ mho and $C = 0.80 \cdot 10^{-12}$ farad. Equation (7a) leads to a value $\beta = 0.48$ and (6a) leads to $\beta = 0.47$. This very close coincidence of the two calculated values for β from two independent measurements gives us faith in the methods laid down above.

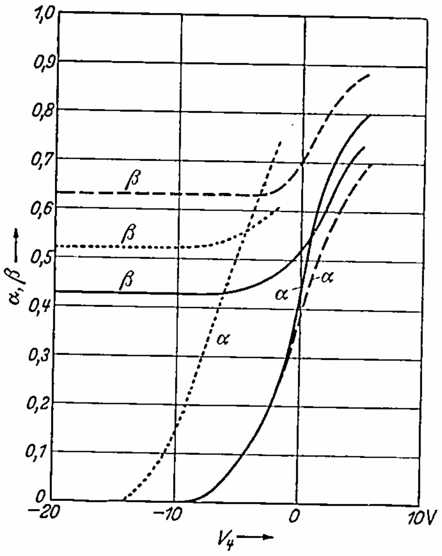

Fig. 8—Vertical α and β. Full and dashed curves refer to the octode AK2. Dotted curves refer to the heptode EH2. Horizontal: voltage on grid 4 for the octode and voltages on grid 3 for the heptode. The other electrode voltages for the octode curves are the same as given for the full and dashed curves of Fig. 5. Electrode voltages for the EH2 are the same as given in the caption of Fig. 2.

From the grid dimensions we may calculate β if we assume (a) the electron paths to be all perpendicular to the surface containing the center lines of the wires of grid 2 and (b) that no returning electrons are absorbed by the cathode. In this case β is equal to the square of the open space between two adjacent grid wires over the distance between the center lines of two adjacent wires. This yields a value of $(190/250)^2 = 0.58$. The measured value of β must always be lower than this, as the two conditions (a) and (b) are not satisfied in practical cases.

We now come to the tube EH2. Considering Figs. 2 and 3 the measured values of C and $1/R$, which have to be inserted into (6a) and (7a) are $C = 0.90 \cdot 10^{-12}$ farad and $1/R = 0.24 \cdot 10^{-4}$ mho. The distance from grid 1 to grid 2 is 0.065 centimeter and the distance from grid 2 to grid 3 is also 0.065 centimeter. Hence $t_1 = 0.52 \cdot 10^{-9}$ and $t_2 = 0.52 \cdot 10^{-9}$ second (at $V_2 = 70$ volts). The value S_k was measured and found to be $1.8 \cdot 10^{-3}$ ampere per volt. Inserting this into (6a) and (7a) both equations yield very nearly $\beta = 0.50$. Again, the values of β calculated from two independent measurements coincide very closely. If we calculate β in a similar way, as was done above in the case of the tube AF3, from the spacing between the wires of grid 2, we find 0.78. The measured value is well under this upper boundary for β.

We have also calculated β and α for the tube EH2 as a function of V_3 (Fig. 8). It is seen that β varies little if α varies from zero to 0.75.

In the case of the octode (Figs. 4 to 7) things are a little more complicated as we shall show, that β is not constant and independent of α. In Fig. 5, the total current I, passing through grid 4 and the currents to grid 3 and grid 2 are shown. The value of I in the case that $\alpha = 1$, will be called I_0. We assume that I_0 gives the value of the current composed of electrons which arrive for the first time before grid 4, coming from the direction of grid 3, for all voltages of grid 4. Thus I_0 is independent of α and β. We have

$$I = I_0 \{ \alpha + \alpha\beta(1-\alpha) + \alpha\beta^2(1-\alpha)^3 + \alpha\beta^2(1-\alpha)^3 + \cdots$$

$$= I_0 \frac{\alpha}{1-\beta(1-\alpha)} \cdot \tag{8}$$

As I and I_0 are known for every value of the voltage V_4 on grid 4 (see Fig. 5), this gives us one equation for the determination of α and β for a given value of V_4. Two more equations are (6a) and (7a), applied to the measured values of Figs. 6 and 7. We may calculate α and β from these three equations and will have one check on each pair of values. These equations yield results, which again coincide very closely, as in the cases dealt with above.

The results of these calculations are shown in Fig. 8. The dotted curves of Fig. 8 refer to the tube EH2. Here, currents similar to those shown in Fig. 5 for the tube AK2, were measured and (8) was applied to these measurements. Whereas β is almost constant for all values of the voltage on grid 3 with the EH2 if α varies from zero to 0.75, a considerable variation of β occurs for the AK2 for a similar variation of α.

V. THE INFLUENCE OF RETURNING ELECTRONS ON THE MODULUS AND ON THE PHASE ANGLE OF TRANSCONDUCTANCE

We consider a valve of the type EH2 (resembling the 6L7) and we measure the transconductance from grid 1 to the anode (Fig. 9) as a function of the voltage of grid 3 on short waves. A considerable influence of this tension of grid 3 on the modulus as well as on the phase angle of transconductance is shown. Numerical expressions for this influence will now be derived. Applying these expressions to measurements of the type shown in Fig. 9, further information on electronic motion in these valves will be obtained.

In section IV the current passing through grid 3 (of a valve type EH2) was called I and the value of I in the case that all electrons are passed by this grid ($\alpha=1$) was called I_0. If V_1 is the voltage on grid 1, we have $S=\delta I/\delta V_1$ and $S_0=\delta I_0/\delta V_1$ for the corresponding transconductance values, measured statically, i.e., with direct- or with low-frequency current. The values of S and S_0, measured on short waves, will be called S_d and S_{0d} (dynamic transconductances). These dynamic values will be complex, each having a modulus and a phase angle. An illustration is given in Fig. 10. In this Fig. 10 the phase angle of αS_{0d} with respect to S_0 is called ϕ_0. The electrons, which return before grid 3 and arrive a second time before this grid contribute an additional phase angle $\phi_1=\omega t$, where t is the total transit-time on their way from grid 3 through grid 2, grid 1, grid 2 back again to grid 3. The components αS_{0d}, $\alpha(1-\alpha)\beta S_{0d}$, $\alpha(1-\alpha)^2\beta^2 S_{0d}$, $\cdots$ have to be added vectorially to yield the final transconductance S_d. We separate S_d into two components, one in the direction of αS_{0d} (see Fig. 10) and a second component perpendicular to this direction. The former component is (see Fig. 10)

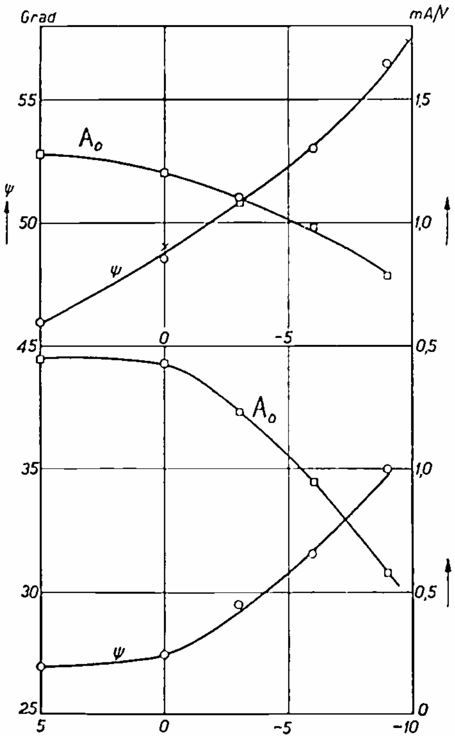

Fig. 9—Modulus A_0 of the transconductance $A_0 \exp(-j\psi)$ from grid 1 to the anode (right scale) and phase angle ψ (left scale) at 8.5 meters wavelength. Upper part for hexode tube AH1, lower part heptode tube EH2. Horizontal scale: voltage on grid 3. Electode voltages as noted for Fig. 2. The two crosses in the upper part are ψ values measured on a different day and show the reproducibility of the measurements.

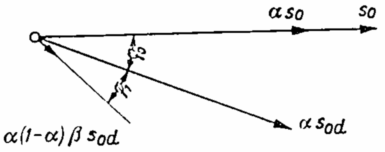

Fig. 10—Transconductance of S_0 and αS_0 (static values); αS_{0d}, where S_{0d} is the value of S_0 measured at short waves, and $\alpha(1-\alpha)\beta S_{0d}$ are shown vectorially.

$$S_{0d}\left\{\alpha+\alpha(1-\alpha)\beta\cos\phi_1+\alpha(1-\alpha)^2\beta^2\cos 2\phi_1+\cdots\right\}$$
$$=S_{0d}\alpha\frac{1-(1-\alpha)\beta\cos\phi_1}{1-2(1-\alpha)\beta\cos\phi_1+(1-\alpha)^2\beta^2}$$

and the latter component is

$$S_{0d}\left\{\alpha(1-\alpha)\beta\sin\phi_1+\alpha(1-\alpha)^2\beta^2\sin 2\phi_1+\cdots\right\}$$
$$=S_{0d}\alpha\frac{(1-\alpha)\beta\sin\phi_1}{1-2(1-\alpha)\beta\cos\phi_1+(1-\alpha)^2\beta^2}.$$

The modulus of S_d is called $|S_d|$. It is found to be

$$|S_d|=|S_{0d}|\alpha\left\{1-2(1-\alpha)\beta\cos\phi_1+(1-\alpha)^2\beta^2\right\}^{-1/2} \quad (9)$$

The phase angle between S_d and S_0 is ψ and $\psi=\phi_0+\psi_0$, where

$$tg\psi_0=\frac{(1-\alpha)\beta\sin\phi_1}{1-(1-\alpha)\beta\cos\phi_1}. \quad (10)$$

As we can easily measure $|S_d|$ and also S, the static value of S_d, it is useful to derive the expression

$$\frac{|S_d|}{S}=\left(\frac{1-2(1-\alpha)\beta+(1-\alpha)^2\beta^2}{1-2(1-\alpha)\beta\cos\phi_1+(1-\alpha)^2\beta^2}\right)^{1/2}. \quad (11)$$

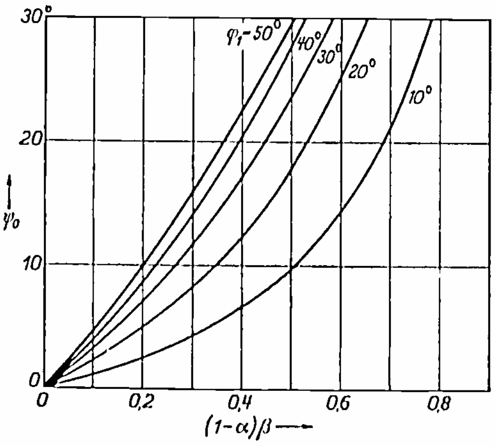

Fig. 11—Values of ψ_0 according to (10) in degrees against $(1-\alpha)\beta$ for different values of ϕ_1 (see (10)).

The expression (10) for the phase angle ψ_0 is illustrated by Fig. 11 and (11) is illustrated by Fig. 12.

VI. APPLICATIONS TO DYNAMIC MEASUREMENTS OF TRANSCONDUCTANCE

From the reasoning of section V it is expected, that $|S_d|$ and S are proportional to the direct current. This is shown in Fig. 13. If the wavelength is chosen in such a manner, that $\phi_1=\omega t \ll 1$, we may take $\sin\phi_1=\phi_1$ and $\cos\phi_1=1$, whereas $tg\psi_0=\psi_0$. Equation (10) yields in this case, making use of (8),

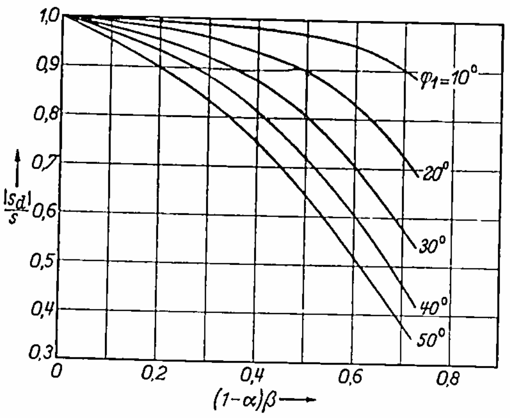

Fig. 12—Values of $|S_d|/S$ according to (11) against $(1-\alpha)\beta$ for different values of ϕ_1.

$$\psi_0=\frac{1-I/I_0}{1-\beta I/I_0}\;\frac{\beta\phi_1}{1-\dfrac{\beta(1-I/I_0)}{1-\beta I/I_0}}=\left(1-\frac{I}{I_0}\right)\frac{\beta}{1-\beta}\,\phi_1. \quad (12)$$

Now the current I is the current to the anode (I_a) and to grid 4 (I_4): $I=I_a+I_4$. The relation between ψ_0 and I is linear (equation (12)). So will be the relation between ψ_0 and I_a. In order to obtain I/I_0 we have to know I_0, which is the value of I in the case that $\alpha=1$. Now I/I_0 will be very nearly equal to I_a/I_{a0}, where I_{a0} is the value of I_a for $\alpha=1$. In Fig. 14 the anode current is measured against the voltage on grid 3. From Fig. 14 we see that $I_{a0}=3.0$ milliamperes for the tube EH2 and 2.0 milliamperes for the AH1. In Fig. 15 the measured phase angle ψ (see Fig. 9) is shown against the corresponding direct current. As is expected from (12) we obtain a linear relationship. This means that β is practically independent of α. If $I_a=I_{a0}$ we have in (12) $I=I_0$ and hence $\psi_0=0$. This occurs at $I_a=3$ milliamperes for the tube EH2 and at $I_a=2$ milliamperes for the tube AH1. For the limiting case $I_a=0$, we see from (12) that ψ_0 is then equal to $\beta\phi_1(1-\beta)^{-1}$. From Fig. 15 we see that $\beta\phi_1(1-\beta)^{-1}$ is 28 degrees for the tube AH1 and 13.5 degrees for the tube EH2. The quantity $\phi=\omega t$ may be calculated from the grid dimensions and the electrode voltages, if we assume that the mean path of a returning electron will be from grid 3 to grid 2 to grid 1 to grid 2 to grid 3. Some returning electrons will have shorter paths and some longer ones. We find $\phi_1=30$ degrees (8.5 meters wavelength) for the AH1 and 14 degrees for the EH2. Hence $\beta(1-\beta)$ is about unity in both cases and β will be very nearly 0.50. This value for the EH2 coincides closely with that derived in section IV from independent measurements.

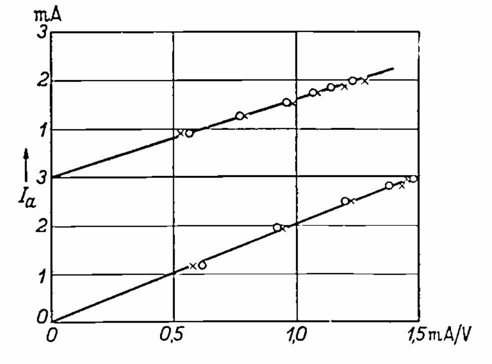

Fig. 13—Vertical: anode current I_a (direct current) in milliamperes. Horizontal: transconductance to the anode measured statically (circles) and dynamically at 8.5 meters wavelength (crosses) in milliamperes per volt. Upper part: tube AH1, lower part tube EH2.

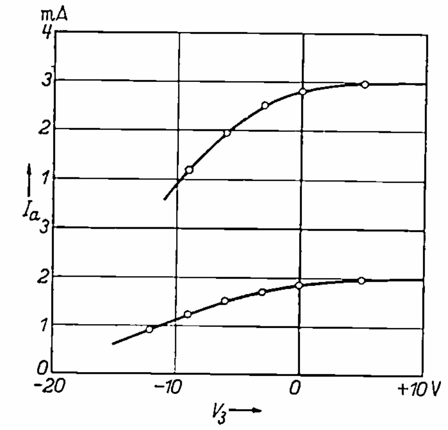

Fig. 14—Anode direct current (vertical) against voltage on grid 3. Upper curve: tube EH2, lower part tube AH1.

A further check on these calculated values for β may be obtained from the data of Figs. 12 and 9.

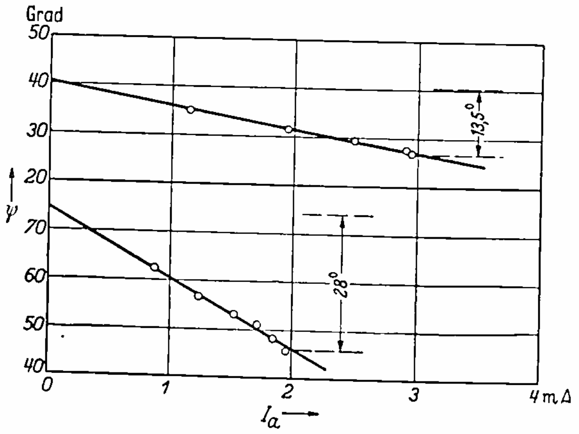

Fig. 15—Phase angle ψ of transconductance (see Fig. 9) against the corresponding anode direct current. Upper curve tube EH2, lower curve tube AH1.

Taking the tube EH2, we find at a voltage -9 volts on grid 3, that $I_a=1.2$ milliamperes and the corresponding value for the AH1 is also 1.2 milliamperes (see Fig. 14). Hence $I_a/I_{a0}=I/I_0=0.40$ for the EH2 and 0.60 for the AH1 at this voltage on grid 3. Taking $\beta=0.50$, (8) yields a value of $1-\alpha=0.57$ for the AH1 and 0.75 for the EH2, in good accordance with Fig. 8. Using these values and the curves of Fig. 12, we find $|S_d|/S=0.93$ for the AH1 and 0.97 for the EH2. The measured values of $|S_d|/S$ were slightly less than unity for both tubes (see Fig. 13), which is sufficient coincidence.

We have also measured the modulus and phase angle of transconductance of an octode valve AK2 on short waves as a function of the voltage on grid 4 (see Fig. 4). These measurements show that the above theory cannot be applied to the AK2.[10] We hope to deal with these features at a future date.

ACKNOWLEDGMENT

The authors express their appreciation for the assistance and helpful criticism given by Dr. K. S. Knol.

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[10] Some of these effects may be partially understood from measurements of J. L. H. Jonker and A. J. W. M. van Overbeek, "A new converter valve," *Wireless Eng.*, vol. 15, pp. 423–431; August, (1938).

Characteristics of the Ionosphere at Washington, D. C., January, 1939*

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AND N. SMITH†, NONMEMBER, I.R.E.

DATA on the critical frequencies and virtual heights of the ionosphere layers during January are given in Fig. 1. Fig. 2 gives the monthly average values of the maximum frequencies

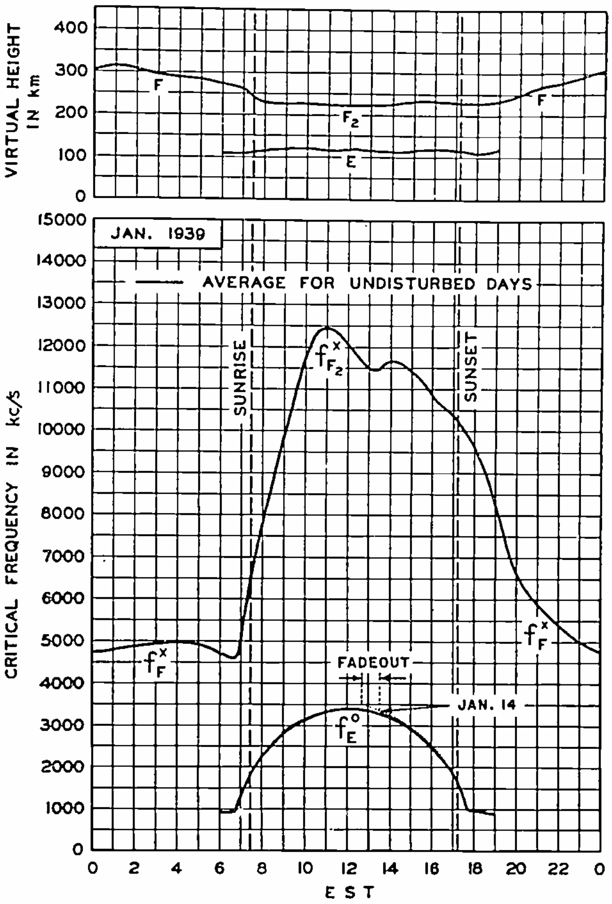

Fig. 1—Virtual heights and critical frequencies of the ionosphere layers, January, 1939. Dotted graph shows $f_E{}^0$ on January 14 when a sudden ionosphere disturbance occurred.

TABLE I
SUDDEN IONOSPHERE DISTURBANCES

Date 1939	G.M.T.		Location of transmitter	Relative intensity at minimum[1]	Remarks
	Beginning of fade-out	End			
Jan. 14	1746	1830	Ohio, Mass. Ontario, D.C.	0.0	Ter. mag. pulse[2] f_E increase[3]

[1] Ratio of received field intensity during fade-out to average field intensity before and after; for station W8XAL, 6060 kilocycles, 650 kilometers distant.

[2] Terrestrial magnetic pulse, observed on magnetogram from Cheltenham Observatory of the United States Coast and Geodetic Survey, simultaneous with the radio fade-out.

[3] Increase of E-layer critical frequency simultaneous with radio fade-out; this is shown in Fig. 1. A similar increase of f_E during a fade-out has been previously reported by Berkner and Wells, *Terr. Mag.*, vol. 42, p. 301, (1937).

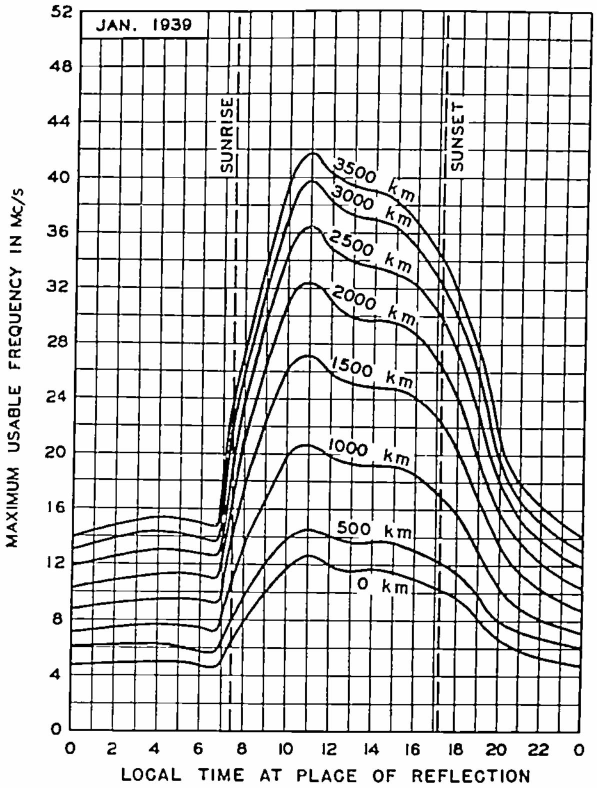

Fig. 2—Maximum usable frequencies for sky-wave radio transmission; averages for January, 1939, for undisturbed days, for dependable transmission by the regular F and F_2 layers.

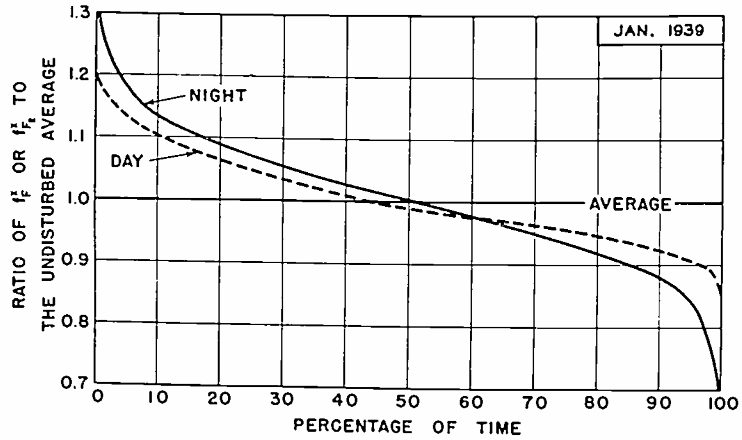

Fig. 3—Distribution of critical frequencies (and approximately of maximum usable frequencies) about monthly average. Abscissas show percentage of time for which the ratio of $f_F{}^x$ or $f_{F_2}{}^x$ to the undisturbed average exceeded the values given by the ordinates. The graphs give data as follows: solid line, 496 hours of night observations, all undisturbed, between 1800 and 0900 E.S.T.; dashed line, 32 hours between 1000 and 1700 E.S.T. on Wednesdays, all undisturbed.

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* Decimal classification: R113.61. Original manuscript received by the Institute, February 10, 1939. These reports have appeared monthly in the PROCEEDINGS starting in vol. 25, September, (1937). See also vol. 25, pp. 823–840, July, (1937).

Publication approved by the Director of the National Bureau of Standards of the U. S. Department of Commerce.

† National Bureau of Standards, Washington, D. C.

which could be used for radio communication by way of the regular layers. Fig. 3 gives the distribution of the hourly values of F- and F_2-layer critical frequencies (and approximately of the maximum usable frequencies) about the average for the month. There were no ionosphere storms during January and only one sudden ionosphere disturbance, listed in Table I, was observed. No ionosphere storm days are plotted in Fig. 1, and none were plotted for November and December, 1938. This is because the ionosphere storms during these months were either mild or entirely absent.

This report inaugurates a new service, the forecasting of radio transmission data for the month following the one in which this report is published. Fig. 4 gives the expected monthly average values of the maximum usable frequencies for radio communication by way of the regular layers, for April, 1939. These estimates had to be made three months in advance. They are based on the observed trends of the critical frequencies in the eleven-year solar cycle and information on diurnal and seasonal variations accumulated over a period of several years. It is believed that the estimates will be accurate within fifteen per cent, for undisturbed days.

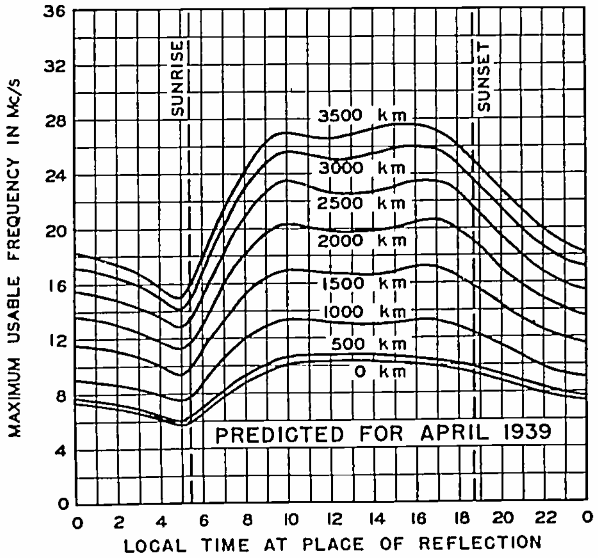


Fig. 4—Predicted maximum usable frequencies for sky-wave radio transmission; average for April, 1939, for undisturbed days, for dependable transmission by the regular F and F_2 layers.

During January no strong sporadic-E reflections were observed at frequencies above six megacycles.

Institute News and Radio Notes

Board of Directors

The February 1 meeting of the Board of Directors was attended by R. A. Heising, president; Melville Eastham, treasurer, H. H. Beverage, Ralph Bown, Alfred N. Goldsmith, Virgil M. Graham, Alan Hazeltine, L. C. F. Horle, C. M. Jansky, Jr., A. F. Murray, Haraden Pratt, B. J. Thompson, H. M. Turner, A. F. Van Dyck, and H. P. Westman, secretary.

P. T. Farnsworth and W. W. Lindsay, Jr., were transferred to Fellow grade. I. F. Byrnes was transferred to Member grade, and E. J. Content was admitted to that grade.

Fifty-five Associates, four Juniors, and twenty-eight Students were elected to membership.

Dr. Weeks, who was invited to serve as a director for 1939, stated it would be impossible for him to give the time necessary to this appointment. I. J. Kaar was designated to serve as a director for 1939.

The Accountant's report was reviewed.

The Secretary's report was considered and an abridgment of it appears elsewhere in this issue.

Mr. Pratt reported on the recent conference held under the auspices of the American Medical Association on the problems of interference caused to communications by the operation of radio-frequency diathermy apparatus. This conference attempted to explore the subject and will probably be followed by further discussions which it is hoped will lead to a solution of this important problem. Users of the equipment, its manufacturers, and radio groups who have suffered interference from its operation were represented.

A report was read on the adoption by the National Broadcasting Company, the Columbia Broadcasting System, and the Bell Telephone Laboratories of a new volume-level indicator and a new standard zero volume level for broadcasting. The new instrument has dynamic characteristics which differ widely from existing instruments and is more highly damped so that violent oscillations of the pointer are avoided. The zero level is based on this new instrument and results under steady-state conditions when one milliwatt is impressed across a 600-ohm circuit. A new designation "vu" numerically equivalent to the number of decibels above the new zero volume level will be adopted.

A report on the Electronics Conference held in New York City on January 13 and 14 disclosed attendance varying between fifty-five and eighty-three at each of the three sessions. Authority was granted for holding another such conference.

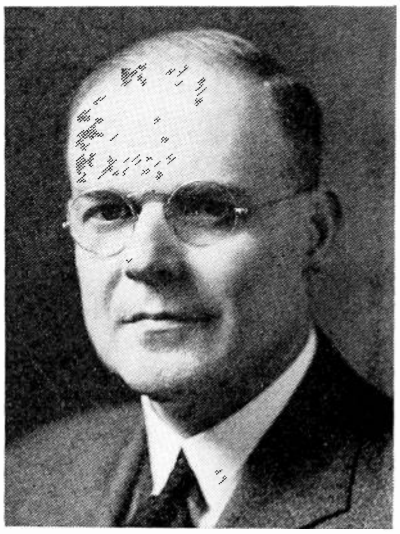
Mr. Pratt was designated the Institute's candidate to serve on the Board of Directors of the American Standards Association in response to an invitation from that organization.

A progress report on early arrangements being made for the convention to be held in San Francisco in June was read.

A contribution to the Engineering Societies Library of $200 was voted.

The President was authorized to appoint a committee to investigate methods of reducing the time lag between the date of receipt of a manuscript and its publication in the PROCEEDINGS.

C. J. BURNSIDE



D. G. LITTLE

A recent announcement from the Westinghouse Electric and Manufacturing Company tells of the transfer of C. J. Burnside from manager of radio engineering to manager of radio sales. D. G. Little, formerly chief engineer, has been named manager of radio engineering.

I.R.E.—U.R.S.I. Meeting

The annual joint meeting of the Institute of Radio Engineers and the American Section of the International Scientific Radio Union will be held in Washington, D. C., on April 28 and 29, 1939. This will be a two-day meeting. Meetings of other important scientific societies will be held in Washington during the same week. Papers on the more fundamental and scientific aspects of radio will be presented. The program of titles will be published in the April PROCEEDINGS and printed abstracts will be available before the meeting. Correspondence should be addressed to S. S. Kirby, National Bureau of Standards, Washington, D. C.

Committees

Annual Review

Two meetings of the Annual Review Committee were required to edit the reports of the six technical committees. These reports are published elsewhere in this issue.

The first on January 25 was attended by A. F. Van Dyck, chairman; E. K. Cohan, J. H. Dellinger, B. Dudley (representing J. K. Henney), D. E. Foster, H. S. Knowles, R. E. Poole (representing E. G. Ports), H. M. Turner, L. E. Whittemore, and H. P. Westman, secretary. The second meeting on January 26 was attended by A. F. Van Dyck, chairman; D. E. Foster, H. M. Turner, L. E. Whittemore, and H. P. Westman, secretary.

Electronics Conference

F. R. Lack, chairman; F. B. Llewellyn, B. J. Thompson, and H. P. Westman attended a meeting of the Electronics Conference Committee on the evening of January 25. The Conference held on January 13 and 14 was discussed and recommendations for the holding of future meetings of this type were prepared.

Sections

Cleveland

A general description of the WTAM transmitter was given by Edwin Leonard, chief engineer. In outlining the preliminary work and difficulties encountered in the development of a new antenna system, he described the temporary antenna, an auxiliary system for emergency use, and the permanent installation. The radiator consists of a triangular tower 470 feet high and 10 feet off the ground. Its top is 1160 feet above sea level and is the highest in the state.

W. S. Duttera of the National Broadcasting Company, then described the antenna input equipment, transmission line, and methods used for the protection of the antenna and its associated apparatus.

A detailed description of the transmitter from the rectifiers to the final amplifiers was then presented by Mr. Russell of WTAM.

These descriptions were followed by a tour of the plant under the guidance of various members of the staff.

November 30, 1938—L. N. Chatterton, chairman, presiding.

To permit complete discussion of the operation of the section, a meeting devoted strictly to business was held. Nominations for officers to be elected at the next meeting were prepared. The desirability and possibility of obtaining a permanent meeting place were discussed as was the material available for future meetings. The usefulness of promoting interest in the section's activities among those in kindred industries and how this might be accomplished received considerable attention. It was agreed that some type of identification tag or badge would be prepared and issued to members to be worn during each meeting.

January 12, 1939—George Grostick, vice chairman, presiding.

Connecticut Valley

"Frequency-Modulation Transmitters and Propagation Characteristics" was the subject of the first paper of the evening which was given by I. R. Weir of the General Electric Company (Schenectady). In it he presented design features of a new type of carrier-stabilized frequency-modulation transmitter which has been used in tests between Schenectady and Albany. Detailed comparative data on the performance of this transmitter and an amplitude-modulated transmitter of the same unmodulated carrier output rating was presented. It was pointed out that an interfering frequency-modulated carrier needs be only slightly more than 6 decibels below the desired frequency-modulated carrier at the receiver second detector to be eliminated from the audio-frequency output, even if the undesired carrier is in the immediately adjacent channel.

Curves were presented comparing amplitude and frequency modulation for a complete transmitting and receiving system on the basis of signal-to-noise ratio. For the Schenectady-Albany region and for the same ratio of signal-plus-noise to noise in the audio-frequency output, a receiver input as low as ten microvolts frequency-modulated was approximately equal to 300 microvolts of amplitude-modulated signal.

The lower initial and operating costs of a frequency-modulated transmitter for a given coverage were illustrated. The paper was concluded with a discussion of propagation data and showed that with ideal geographical transmitter spacings, it would be more economical to serve a given territory with a frequency-modulated system than one employing amplitude modulation.

A paper by G. W. Fyler and J. A. Worcester of the General Electric Company (Bridgeport), on "The New Armstrong Frequency-Modulation Receiver," was presented by Mr. Fyler. He discussed the type of receiver now being produced by the General Electric Company. This receiver had in its second detector a circuit derived from the well-known automatic-frequency-control diode circuit used in earlier receivers. The intermediate-frequency amplifier has a very linear frequency-shift versus audio-frequency-amplitude response for a frequency variation of 100 kilocycles on both sides of the mean carrier frequency.

Descriptions were then given of the radio-frequency amplifier, the converter which employs a separate oscillator, intermediate-frequency amplifier, limiting stage, frequency-discriminating audio-frequency stage, audio-frequency amplifier, and power supply. Phase variation is used in the audio-frequency system to obtain push-pull output. To improve the acoustic output of the receiver, a special-edge curvilinear cone was developed for the loud speakers used. Over-all characteristics from the studio to the receiver acoustical output were shown and the paper was concluded with a discussion of factors affecting the design of practical high-fidelity receivers.

E. H. Armstrong, who developed the system of transmission being discussed, described the transmitters and studio equipment to be used in the demonstration which was part of the meeting. Test material was transmitted from Alpine, N. J., on a frequency of 42.8 megacycles with an output of 20 kilowatts. Recorded material was supplemented by a live-talent program relayed by Alpine, N. J., from Yonkers, N. Y. Six of the new receivers were used for reception.

Messrs. DeMars, Doolittle, and Noble described and presented pictures of frequency-modulation transmitters and antenna installations now being constructed on several mountain tops in New England.

January 19, 1939—E. R. Sanders, chairman, and W. R. G. Baker, secretary, presiding.

Emporium

D. H. Black of Standard Telephones and Cables (England), presented a paper on "Ultra-High-Frequency Oscillators." The subject was introduced by Dr. Black with a brief review of various types of oscillators. He limited his paper to negative-grid oscillators and pointed out that among the interdependent limitations are available cathode emission, plate dissipation, grid emission, lead inductance, interelectrode capacitance, and transit-time. The mechanical design of several types of high-frequency vacuum-tube oscillators was then illustrated. A circuit with which frequencies as high as 1600 megacycles had been obtained was described. It was pointed out that some of the phenomena exhibited by this circuit could best be explained by variation of capacitance with frequency. A formula which showed that capacitance was inversely related to wavelength was given.

The paper was discussed by Messrs. Acheson, Baldwin, Carter, and Miller.

January 31, 1939—R. K. McClintock, chairman, presiding.

Montreal

C. F. Baldwin of the General Electric Company (Schenectady), presented a paper on "Quartz-Crystal Theory, Practice, and Manufacturing." It was stated that the best raw material comes from Brazil and occurs in crystals about six inches to a foot in length, costing about $10.00 per pound. The wastage in cutting is about ninety-five per cent. The development of the various cuts and their characteristics were described. Various types of mountings and their characteristics were covered.

December 14, 1938—S. Sillitoe, chairman, presiding.

"Aircraft Communication and Navigation" was the subject of a paper by S. S. Stevens, technical advisor on communications to Trans-Canada Air Lines. He presented first a historical sketch of the development of aircraft radio from the days of the war when weight and low-powered equipment prevented very successful operation to the present when it is indispensable to air lines.

The four- and five-tower beacon and weather transmitters were described and the advantages of simultaneous reception of weather reports and beacon signals from the latter-type installation were pointed out. The Trans-Canada system makes use of beacons installed at approximately 100-mile intervals from Montreal and Toronto to Vancouver, which are operated by the Department of Transport of the Dominion Government. Routine traffic and weather reports between main ground stations are handled by multichannel transmitters, the frequencies of which are selected by dialing. Several marker beacons are contemplated to provide reference points for pilots where these are found desirable.

The meeting was closed with the showing of a film supplied through the courtesy of the United Air Lines and entitled "Coast to Coast by Air."

January 11, 1939—S. Sillitoe, chairman, presiding.

Pittsburgh

A round-table discussion on "Recent Developments in Broadcast Transmission and Reception" was led by J. E. Baudino, chief engineer of KDKA. The discussion touched on a large number of items among which were response characteristics of the eight-ball and ribbon or velocity-type microphone. A description of the Western Electric remote-pickup resonant-type collector with its dynamic microphone was given and the equipment exhibited. The National Broadcasting Company Hollywood studios were described. Loud speakers with loading in the base range, high-efficiency amplifiers, directional antennas, transmission lines, and pressure-type gas-filled condensers were also discussed. The meeting was closed with a review of the trends in 1939 broadcast receivers given by J. S. O'Shea of Midwest Radio.

January 17, 1939—W. P. Place, chairman, presiding.

Portland

This meeting was devoted to a tour of inspection of the toll facilities of the Pacific Telephone and Telegraph Company which was under the guidance of R. W. Deardorff transmission and protection engineer for that company.

January 18, 1939—H. C. Singleton, chairman, presiding.

Seattle

"Properties and Application of Tapered Radio-Frequency Transmission Lines" was the subject of a paper by T. M. Libby, engineer for the Pacific Telephone and Telegraph Company. He reviewed briefly some of the properties of the uniform transmission line, demonstrating mathematically that it could be used as an impedance transformer at a given frequency. A short history of the tapered transmission line led to a discussion of the exponential line which formed the basis for the remainder of the paper. This line employs conductors so spaced that the distributed capacitance and inductance vary exponentially with distance along the line. It was shown to be a high-pass impedance-transforming filter. Performance curves of a specific line showed that it maintained, within six per cent, an impedance ratio of 600 ohms to 300 ohms over a range from 4 to 30 megacycles. Some uses for such lines were in coupling a rhombic antenna to a 600-ohm transmission line and in coupling a coaxial cable to an open-wire line.

January 13, 1939—R. O. Bach, chairman, presiding.

Membership

The following indicated admissions and transfers of memberships have been approved by the Admissions Committee. Objections to any of these should reach the Institute office by not later than March 31, 1939.

Transfer to Member

Barhydt, C. R., General Electric Co., Bridgeport, Conn.
Brainerd, J. G., Moore School of Electrical Engineering, University of Pennsylvania, Philadelphia, Pa.
Decino, A., 229 Lawrence Ave., Elberon Park, N. J.

Admission to Associate (A), Junior (J), and Student (S)

Alfonso, J. S., (S) 31 Hill St., Orono, Maine.
Barta, V. P., (S) 2916 S.E. 36th Ave., Portland, Ore.
Binns, A. W., (A) 7 Shelley Rd., Coventry, Stoke, England.
Bolen, R. E., (A) 1602 Carey La., Silver Spring, Md.
Brown, R. H., (A) The Nenk, Highbeech, Felixstowe, Suffolk, England.
Burchill, G. H., (A) Nova Scotia Technical College, Halifax, N.S., Canada.
Chu, L. J., (A) 290 Massachusetts Ave., Cambridge, Mass.
Cochran, L. B., (A) 305 Engineering Hall, University of Washington, Seattle, Wash.
Crossfield, G. B., (A) 29 Bradley Rd., London S.W. 19, England.
d'Ayala Valva, G., (A) Corso Mentana 31–10, Genova, Italy.
de Figuieredo, B. F., (A) City and Guilds Engineering College, Exhibition Rd., London S.W.7, England.
Dell, E. J., (A) Morlais, Swansea Rd., Loughor, Gorseinon, Glam., Wales.
Dominick, J., (S) 837 W. 36th Pl., Los Angeles, Calif.
Eastman, P. J., (A) 24 Parkway S., Mount Vernon, N. Y.
Egan, D. G., (A) c/o R. L. Suggs, Geological Dept., Humble Party N.K.P.M., Soengei Gerong, Palembang, Sumatra, Nederlands Indies.
Fielding, E. A., (A) "Redesmere," 4 Manor Rd., Oldham, Lancs., England.
Frazier, R. E., (S) 414 N. Salisbury, West Lafayette, Ind.
Gamo, T., (A) JOAK Hatogaya Broadcasting Station, Hatogaya-machi, Saitama-ken, Japan.
Gates, H. P., Jr., (S) 2315 Dwight Way, Berkeley, Calif.
Ginzton, E. L., (S) 1260 Second Ave., San Francisco, Calif.
Goodell, E. M., (S) 332 Virginia Ave., San Mateo, Calif.
Green, A. P., (S) 1143 N. Edgemont St., Los Angeles, Calif.
Griffin, H., (A) 20 Birstall Rd., Birstall, Leics., England.
Grimley, E. C., (A) 765 Lexington Ave., Westmount, Montreal, Que., Canada.
Harris, N. M., (S) 4815 N.E. Eighth Ave., Portland, Ore.
Hayes, J. E., (A) Canadian Broadcasting Corp., Keefer Bldg., Montreal, Que., Canada.
Heim, H. J., (A) 206 Dehart St., West Lafayette, Ind.
Hermon, F. E., (A) 2901 N. Kilbourn Ave., Chicago, Ill.
Holden, G. A., (A) 228 St. Helen's Ave., Toronto, Ont., Canada.
Hook, J. W., (A) 728 Gladys Ave., Long Beach, Calif.
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Horsfall, J., (A) 5 Buckingham Pl., Westminster, London, England.
Hutton, E. W., (S) 480 Spruce St., Morgantown, W. Va.
Inokuchi, S., (A) JOJK Nonoichi-cho, Kanazawa-Shigai, Japan.
Istvanffy, E., (A) Standard Electric Co., Ltd., Budapest, Hungary.
Jones, R. L., (A) 314 E. Eighth St., Pittsburg, Kan.
Jorysz, A., (A) 448 E. 178 St., New York, N. Y.
Kelsey, A. L., (A) 714½ N. Edinburgh, Los Angeles, Calif.
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Lawrence, W., (A) The Plessey Co., Ltd., Vicarage Lane, Ilford, London, England.
Lempert, I. E., (S) Taylor Hall, Section D, Bethlehem, Pa.
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Macdonald, G. E., (A) c/o Radio Station CFAC, Calgary, Alta., Canada.
Malvarez, L. M., (A) 47 y 1, Dep. Electrotecnica, La Plata, Argentina.
McKinley, D. W. R., (A) 91 MacLaren Ave., Ottawa, Ont., Canada.
Mellon, D. C. H., (A) c/o Port Directorate, Basra, Iraq.
Millen, E. R., (A) The Bell Telephone Co. of Pennsylvania, 416 Seventh Ave., Pittsburgh, Pa.
Miller, R. H., Jr., (S) 1328-106th Ave.. Oakland, Calif.
Morse, C. H., (A) 506 First Ave., W., Seattle, Wash.
Nebel, R. E., (A) 1104 Lincoln Pl., Brooklyn, N. Y.
Ogawa, G., (S) 1603 Opal St., Pullman, Wash.
Omalanz, W., (J) 2636 W. 63rd St., Seattle, Wash.
O'Shea, J. G., (A) 30 E. Orchard Ave., Bellevue, Pa.
Petrak, J. R., (S) 1943-19th Ave., San Francisco, Calif.

Pfitzer, C. C., (S) 2919 Minot Ave., Cincinnati, Ohio.
Post, D., (A) Station KOBH, Rapid City, S. D.
Preston, G. F., (J) 1631 Lafayette Ave., Columbus, Ind.
Quigley, A. J., (S) 10 Weld Ave., Roxbury, Mass.
Ramalingam, C. V., (A) 11 Fourth St., Gopalapuram, Cathedral P.O., Madras, India.
Rapp, W. J., (A) Tweed St., Coolargatta, Queensland, Australia.
Rice, H. E., (A) 421 W. 21st St., New York, N. Y.
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Smith, C. J., (A) 645 S. Mariposa St., Los Angeles, Calif.
Smith, E. P., (S) 2413 Grove St., Berkeley, Calif.
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Vollum, E. O., (S) 2425 College Ave., Berkeley, Calif.
Wade, N. G., III, (S) M.I.T. Dormitories, Cambridge, Mass.
Webb, H. A. J., (A) 48 Bow St., Beverly, Mass.
Webster, J. M., (S) 2040-23rd Ave., N., Seattle, Wash.
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Wing, W., (S) 206 S. Darling St., Angola, Ind.
Wolf, L., (A) 41-11 Ave., Haddon Heights, N. J.
Wong, M. S., (S) 107 S. Riverside Dr., Ames, Iowa.
Yeh, L. P., (S) 37 Mellen St., Cambridge, Mass.

Correspondence

Time

The question of G.C.T. (Greenwich Civil Time) versus G.M.T. (Greenwich Mean Time) has been raised by persons who have had correspondence between engineers engaged in radio research and scientists engaged in astronomical work. Since these two fields of research are becoming more and more interrelated, the necessity for a definite terminology, which shall be uniform, becomes more apparent. The following definitions are copied from *Navigation and Nautical Astronomy* by Captain Benjamin Dutton, United States Navy, Fifth Edition, dated 1934.

THE MEAN SUN. The mean sun is an imaginary sun which moves to the eastward in the equinoctial at a uniform rate equal to the average rate of the true sun in the ecliptic.

MEAN TIME. Time measured by the apparent motion of the mean sun is called mean time.

CIVIL DAY. A civil day is the interval between two successive transits of the mean sun across the lower branch of the meridian.

CIVIL TIME. Mean time with the origin of the day at lower transit of the mean sun is called civil time. Civil time at any place equals the hour angle of the mean sun plus twelve hours, dropping twenty-four hours if the sum exceeds that amount.

The following is also copied from the same book, Section 109, page 142:

" . . . Formerly navigators considered the day as beginning at the instant the sun crossed the upper branch of the meridian, i.e., at noon. Mean time, with the beginning of the day at that instant, is called astronomical time. Navigators now use the instant of transit of the sun across the lower branch of the meridian (midnight) as the beginning of day. Time so reckoned, i.e., by the apparent motion of the mean sun with the instant of lower transit as the origin of the day, is called civil mean time, or more commonly, civil time . . . ."

It is also to be noted that all tables in the *American Ephemeris and Nautical Almanac* are headed "Greenwich Civil Time." At the bottom of these tables there is also the note: "0^h Greenwich Civil Time is twelve hours before Greenwich Mean Noon of the same date."

The following is quoted from *Astronomy* by Robert H. Baker: "CIVIL TIME is the specific reckoning of mean solar time from midnight through twenty-four hours continuously. It is the hour angle of the mean sun plus twelve hours. Until the beginning of 1925, astronomical mean time was reckoned from noon, and was twelve hours later than civil time. Now the two are the same . . . ." It is interesting to note, however, that this author also specifies "local civil time," and not local mean time, in sample calculations.

Briefly, "mean time" has no reference point from which the day starts. "Civil time" is mean time referred to a definite reference point. It, therefore, is specific.

In view of the foregoing, it would seem that the wise course for radio men to pursue would be to employ the terminology "Greenwich Civil Time," as adopted by, and used in the *American Ephemeris and Nautical Almanac*. There would then be no confusion.

J. B. Moore
P.O. Box 235
Riverhead, L.I., N.Y.

Books

Radio Facsimile

Published by RCA Institutes Technical Press, 75 Varick Street, New York, New York. 353 pages.

Image transmission has made rapid strides during the last decade. Depending on such factors as the speed of transmission, degree of detail, and faithfulness of tone reproduction, it must, for careful study, be considered in separate categories. Thus, we have television, facsimile, telephotography, etc.; also, there are the two alternative transmission media, wire and radio transmission. As the preface explains, it is believed that radio facsimile seems entitled to more attention in the literature than it has hitherto received. Hence this Volume I of "Radio Facsimile," published by the RCA Institutes Technical Press, which assembles between one set of covers the combined records of the RCA technical experts, under the editorship of Alfred N. Goldsmith, A. F. Van Dyck, C. W. Horn, R. M. Morris, and Lee Galvin. Not only is this a compilation of the more recent papers on the subject, but it includes reprints of former articles, including the pioneering efforts of R. H. Ranger, in order to round out a complete story of the RCA efforts in this direction. Those whose articles have been recorded include R. H. Ranger, V. K. Zworykin, Alfred N. Goldsmith, J. L. Callahan, Henry Shore, M. Artzt, J. N. Whitaker, R. E. Mathes, J. E. Smith, H. H. Beverage, W. H. Bliss, C. J. Young, F. C. Collings, I. F. Byrnes, and D. E. Foster.

This compilation includes only those papers coming under the strict category of radio facsimile, and whose authors are or have been RCA men. To this extent it is not a complete record of the art. However, the individual papers naturally contain many related references to the work of others, and in the field of wire transmission; also, J. L. Callahan is the author of a very complete bibliography of literature and patents on the subject.

Radio facsimile has definite possibilities. Just what its future may be as a broadcast news disseminator in competition with or to supplement newspapers and voice or perhaps television broadcasting perhaps remains to be demonstrated. In any case, the communication engineer cannot afford to overlook this publication, which is evidently intended to be expanded from time to time by further volumes as the art develops.

H. A. Affel
Bell Telephone Laboratories, Inc.
New York, N. Y.

The Radio Amateur's Handbook. (Sixteenth, 1939 Edition)

Published by American Radio Relay League, West Hartford, Connecticut. 560 pages including 104-page catalog section of amateur radio equipment. Approximately 815 illustrations and 50 charts and tables. Price paper-bound, $1.00 in continental U.S.A.; $1.25 elsewhere; buckram-bound, $2.50.

The book contains an introductory section on fundamentals and theory followed by sections on vacuum tubes, receiver design and construction, transmitter design and construction, various types of signaling, ultra-high-frequency technique, antennas, instruments and measurements, and power supply. There are also sections pertaining to station operations and message handling.

The information is up to date and well presented. In general, the choice of material and presentation are of such nature as to make them particularly suitable to the requirements of the radio amateur and home experimenter.

This edition of the Handbook is dedicated to the late Ross A. Hull, for ten years editor of the volume and who contributed so much to the advancement of radio. Publication was carried to conclusion by the remaining collaborating members of the ARRL Headquarters staff, but the book still bears the unmistakable impress of Hull's editorial guidance.

H. O. Peterson
R.C.A. Communications, Inc.
Riverhead, L. I., N. Y.

Testing Television Sets, by J. H. Reyner.

Published by Chapman and Hall, London, England. 128 pages. 49 illustrations. Price 9/6.

After two years of commercial television in England it would seem that the time was ripe for a book covering the location of and the remedy for television receiver faults. After reading Mr. Reyner's book on this subject I wonder if this is true.

Whoever writes such a book is beset with the following problems: Should I write for the serviceman or the engineer? Should I discuss faults in properly designed receivers, or should I warn of faults due to improper design? With thirty-odd makes of receivers on the market, each differing widely, how can I give concrete, all-inclusive remedies? Shall I describe the functioning of the units or assume the reader knows the technical operation of a television receiver? These are difficult questions.

Our author's approach is by first mentioning the apparatus required for testing He then lists very briefly some of the locations of trouble. The chapters that follow are: Faults in Cathode-Ray Tubes, Faults in Time Base Units, Synchronizing Units, Receiver Faults, Interference, and Laboratory Technique.

The book is clearly written and illustrated. Unfortunately the subject is dealt with in a manner not elementary enough for one unfamiliar with television technique, and yet too elementary for the television engineer. It is doubtful if this book will be of much value to television workers in America.

A. F. Murray
Philco Radio and Television Corporation
Philadelphia, Penna.

Experimental Radio by R. R. Ramsey. (Fourth Edition)

Ramsey Publishing Company, Bloomington, Indiana. 196 pages. 167 figures. Price $2.75.

The present edition is a revision, after ten years, of a laboratory course manual intended primarily for college sophomores. The changes involve particularly the substitution of alternating-current supplies for batteries. The increase in size of the manual is also noticeable. The circuit diagrams and graphs are not all that might be desired. The former, in many cases, show a circle for a lamp as a resistance rather than the conventional zigzag line and, in some places, rather rough hand-drawn circuits. The graphs are sometimes drawn on too small a scale for easy use. The apparatus seems to be largely home-built and the author gives instructions by which students can make their own apparatus. Any budding radio amateur using the book will be disappointed to find that the only mention of a crystal has to do with the contact-detecting kind, that there is almost no work that is obviously with ultra-short waves, and that multielectrode tubes are almost neglected.

Unfortunately, the book is loose in the use of English and the punctuation is often misleading. One gathers the impression that as it outgrew the loose multigraphed-sheet state, the copy went into the print shop without the usual editing. The reference to "Darrell Green's thesis" in the text without a footnote as to where that document may be found confirms the general impression that the book is intended primarily for local consumption. Oddly enough, following "Darrell Green" the inclusion of "Seibt's Experiment" without a reference to the literature made the reviewer wonder at first whether Seibt was a local student, for he had to search all the way back to the Fleming text to find in English any reference to this active figure in the early days of radio.

In the preface the author states it as

one of his objects to correct the false perception which "a large per cent of physicists still cling to," regarding the relation between beats and the side-band tones in modulation. But it seems to the reviewer, a physicist, that the confusion which does still exist to some extent would be increased rather than decreased by the author's references.

The above is perhaps unduly harsh criticism of the details of a set of notes on laboratory experiments. The list of one hundred and thirty experiments is an excellent one. The range of choice is wide and the instructions to the experimenter are well handled and appropriate. The page references to standard technical literature which are given in connection with most of the experiments are a very valuable feature.

K. S. VAN DYKE
Wesleyan University
Middletown, Conn.

The Radio Manual, by George E. Sterling. (Third Edition)

Published by D. Van Nostrand Company, Inc., 250 Fourth Avenue, New York, New York, 1107 pages. Price $6.00.

The third edition of The Radio Manual is a comprehensive text and a reference designed for those preparing to enter the radio profession as engineers, inspectors, and operators as well as those engaged in such activity and in addition to those interested in instrument flying where the use of radio aids to air navigation are utilized and necessary. The book is profusely illustrated with circuit diagrams and apparatus.

The author has secured the collaboration of several experts in the preparation of this edition, notably Robert S. Kruse, E.E., who in the past assisted in an editorial capacity, and Wm. R. Foley, E.E.

The first three chapters are devoted to the fundamentals of electricity, magnetism, storage batteries, and motor generators.

Chapters 4 and 5 include an excellent treatment of the electron tube as used in modern communication systems. Chapter 4, written by Mr. Kruse, contains not only elementary information for the beginner in radio, but takes that beginner in successive steps through the characteristics of the electron tube and its varied applications in receivers and transmitters. In addition, it describes and analyzes the various fundamental circuits employed in radio receivers and transmitters.

Chapter 5, written by Mr. Foley is a treatise on the various classes of both audio- and radio-frequency amplifiers, computation of the efficiency of such amplifiers, driving and output circuits, methods of neutralization and procedure, and cause and prevention of parasitic oscillations. To assist the student with a weak mathematical background, practical examples of the solution of problems are included throughout the chapter.

Chapters 6 and 7 include the elementary principles of modulation systems, modulation analysis, principles of operation and characteristics of microphones, mixing circuits, impedance-matching networks, program amplifiers, methods of making frequency runs, and a description of the characteristics of instantaneous recording systems.

Chapters 8 to 16 inclusive, describe in detail the latest types of radio equipment employed in broadcast, ship, aircraft, aeronautical, and police stations. The author recognizes the advantage of quoting directly from the instruction books with respect to the operation, service, and repair of the equipment since it permits a beginner to become familiar with the particular language of the art and thereby permits him to read himself into current practice. Chapter 14 describes the characteristics of radio ranges, instrumental landing systems, and in addition includes an elementary course in the use of radio aids to air navigation, amplified by several problems in orientation and homing.

Chapter 15 furnishes complete information covering the description, operation, correction of faults, and maintenance of auto-alarm receivers and associated apparatus employed on United States cargo vessels to satisfy the requirements of law having for its purpose the promotion of safety of life and property at sea. International radio law requires that the auto-alarm signal shall be transmitted prior to the SOS signal and serves to actuate the selective ringing circuit associated with an auto-alarm receiver thereby summoning the operator of a ship within communication range to the radio room in time to intercept the details of the distress message.

The last three chapters of the book include important extracts from the Communications Act of 1934 as amended, the General Radio Regulations of the Telecommunication Convention of Cairo, and rules and regulations of the Federal Communications Commission. The inclusion of this material enchances the value of the book for those preparing for examination for radio operator's license as well as engineers and operators engaged in the operation of radio stations of all classes.

The principal errors in the book are the omission of a figure associated with the text on page 124 and in figure 147 on page 242 showing the neutralizing condenser connected to the wrong side of the radio-frequency choke.

T. A. M. CRAVEN
Federal Communications Commission
Washington, D. C.

History of Radio to 1926, by Gleason L. Archer

Published by The American Historical Society, Inc., 80 Eighth Avenue, New York, New York. 421 pages. Price, $4.00.

The first half of this book consists of a compilation of historical data which have in general been available in previously published books. The first twelve chapters cover the range from signaling in the days of Troy through the invention of the telegraph, the telephone, and radio; the laying of transoceanic cables; and the organization of the radio communication enterprises which are active in the world today.

Beginning with Chapter 13, which is entitled "Pioneer Days in Radio Broadcasting," the book consists, to a substantial degree, of a compilation of facts which are otherwise available only in scattered locations. The author states that it has been his endeavor to rescue from oblivion historical material which existed only in contemporary records of a perishable nature.

To those who are interested in the early days of broadcasting and especially to those who were active in that field during the years 1900 to 1926, the second half of the book will have peculiar interest. Quotations are made from the files of early broadcast organizations; references are made to editorials which appeared in the magazine, *Radio Broadcast*, a pioneer in this field. Statements by leaders of the broadcast industry are cited giving predictions as to the economic basis on which broadcasting would find its support. Stories are told about some of the earlier broadcast presonalities such as the Happiness Boys, Roxy and his Gang, and the Atwater Kent radio artists. "Alabama, twenty-four votes for Underwood" recalls the early service of broadcasting in the political field.

In some respects, notably in connection with patents, it seems doubtful whether the author has collected all of the pertinent facts, and this has led to some doubtful conclusions. In spite of this, however, the book makes interesting reading. The author states that he is already at work collecting historical data on radio for the twelve-year period since 1926.

L. E. WHITTEMORE
American Telephone and
Telegraph Company
New York, N. Y.

Report of the Secretary—1938

This report is published so the membership may be informed of the more important factors affecting the operation of the Institute.

General

The membership decreased slightly during 1938 and the amount of editorial material appearing in the PROCEEDINGS was reduced by a few per cent. A small operating loss was incurred. General business conditions and those specifically met by the radio industry in the United States during the last quarter of 1937 and the major part of 1938 are ample reasons for the reduction in membership and income. The latter was solely responsible for the decrease in PROCEEDINGS pages.

Membership

The paid membership at the end of the year was 5403 as compared with 5459 in 1937, a decrease of one per cent. The membership outside of the United States continues at about twenty-four per cent of the total. Fig. 1 shows the variation of membership throughout the life of the Institute.

Ten Fellows and forty-six Members were transferred or admitted directly to those grades and the distribution of membership by grades is shown in Table I.

TABLE I
MEMBERSHIP DISTRIBUTION BY GRADES

Grade	Number	Per Cent
Fellow	156	2.9
Member	645	11.9
Associate	4250	78.7
Junior	38	0.7
Student	314	5.8

There were 697 new members admitted to the Institute in 1938 compared with 751 in 1937.

Proceedings

Volume 26 of the PROCEEDINGS contains 1568 pages of editorial material, about five per cent fewer than the 1654 pages published in 1937. Data on the size of the PROCEEDINGS are given in Fig. 2.

A new format for the PROCEEDINGS was approved and Volume 26 was the last published in the small size.

There were 123 papers reviewed by the Papers Committee and 152 by the Board of Editors. Of these, 104 were accepted for publication, 21 were returned for revision, and 19 were rejected. In addition, 16 book reviews were prepared and published.

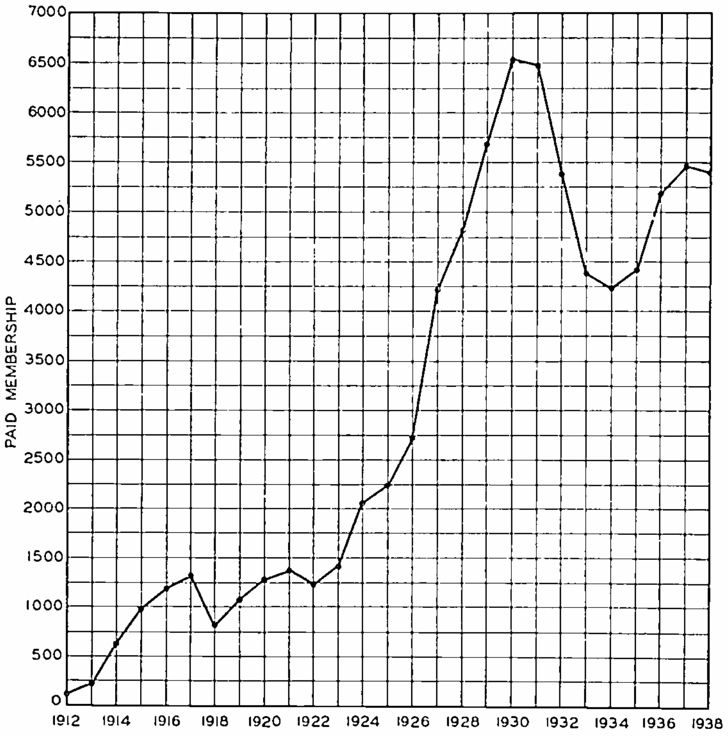


Fig. 1

Sections

Sections activities are indicated in Table II. A new section was established in Portland, Oregon.

Meetings

There were 183 section meetings, 8 New York meetings, and 4 conventions held.

On April 29 and 30, a meeting was held jointly with the American Section of the International Scientific Radio Union (U.S.R.I.) in Washington, D. C. Twenty-nine papers were presented and about 150 were present.

The Thirteenth Annual Convention was held in New York City on June 16, 17, and 18. There were forty-nine papers presented. The attendance of 1766 men and 100 women was about fifty per cent greater than at any previous Institute meeting.

On the Pacific Coast, a meeting was held in Portland, Oregon, at which nineteen papers were presented. The registration for the two days, August 10 and 11, was 121 men and 23 women. This meeting was co-ordinated with the convention of the American Institute of Electrical Engineers.

In Rochester, New York, the Annual meeting on November 14, 15, and 16 attracted an attendance of 477. There were fifteen papers presented.

TABLE II
SECTION MEMBERSHIP AND MEETINGS

Section	Membership Dec. 31, 1938	Meetings Held			1938 Average Attendance*	1938 Per Cent Attendance
		1936	1937	1938		
Atlanta	20	10	10	11	27	135
Boston	216	5	6	—	—	—
Buffalo-Niagara	39	7	10	10	40	103
Chicago	275	10	10	14	197	72
Cincinnati	82	9	8	10	69	84
Cleveland	72	8	7	5	34	47
Connecticut Valley	80	8	7	5	42	52
Detroit	99	10	10	10	74	75
Emporium	90	14	15	12	51	57
Indianapolis	39	—	10	6	25	64
Los Angeles	194	11	8	11	152	78
Montreal	80	—	5	9	101	126
New Orleans	21	1	6	2	60	286
Philadelphia	327	9	8	9	206	63
Pittsburgh	51	8	9	11	47	92
Portland**	44	—	—	1	28	64
Rochester***	39	10	12	10	—	—
San Francisco	162	14	17	17	40	25
Seattle	40	8	10	9	54	135
Toronto	88	8	12	11	97	110
Washington	282	11	9	10	146	52
	2340	161	189	183	85	75

* Does not include joint meetings with other societies. ** Established, December, 1938.
*** Seven meetings credited for 1938 Rochester Fall Meeting. All meetings held jointly with other societies.

Committees

Our committees held 53 meetings. In addition, a number of committees are able to operate without meetings as their work may be accomplished by correspondence. This is particularly true of the Papers Committee and Board of Editors. The meetings of the latter body were entirely devoted to the development of the new PROCEEDINGS' format.

Standards

Four standards reports, Electroacoustics, Electronics, Radio Receivers, and Transmitters and Antennas were published and replace the 1933 report.

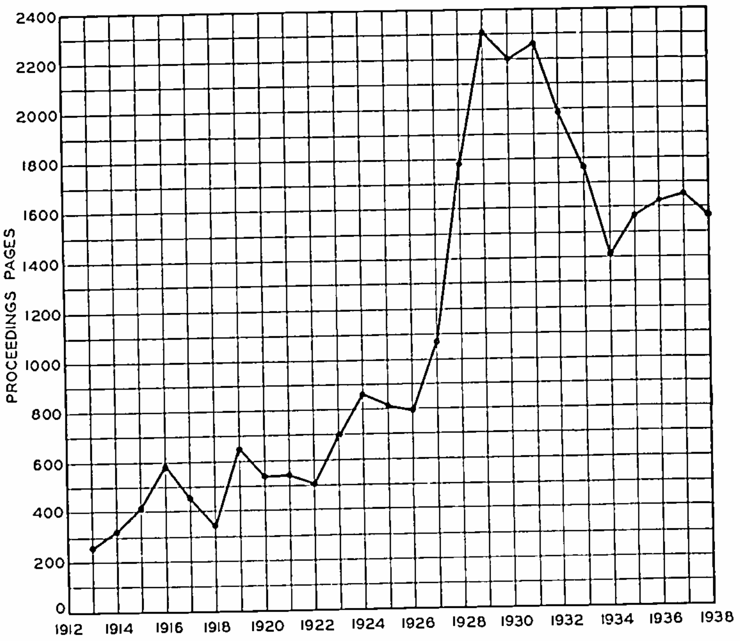


Fig. 2

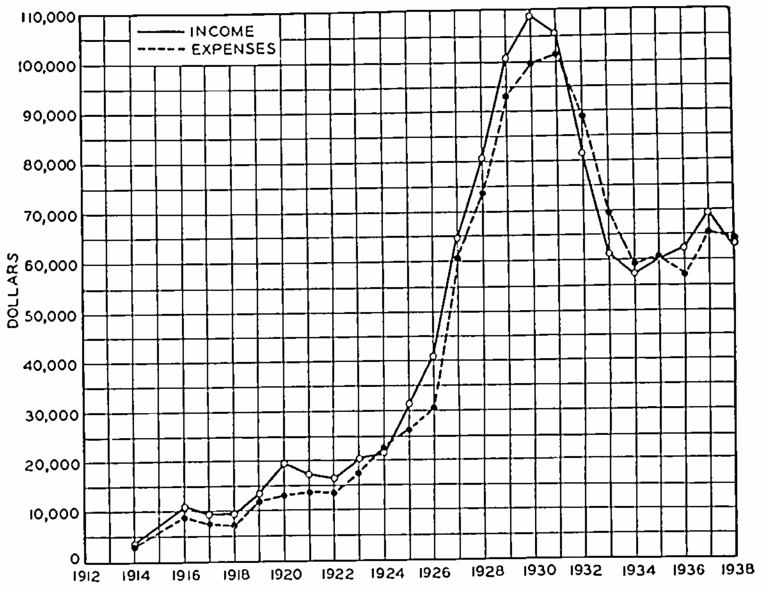


Fig. 3

Constitution

A revision of the Institute Constitution was prepared and distributed to the membership for ballot. The results of the ballot will not be known until early in 1939.

Awards

The Institute Medal of Honor was awarded to John Howard Dellinger for his contributions to the development of radio measurements and standards, his researches and discoveries of the relation between radio-wave propagation and other natural phenomena, and his leadership in international conferences contributing to world-wide co-operation in telecommunications.

The Morris Liebmann Memorial Prize was awarded to G. C. Southworth for his theoretical and experimental investigations of the propagation of ultra-high-frequency waves through confined dielectric channels and the development of a technique for the generation and measurement of such waves.

The PROCEEDINGS Paper Prize was given to A. L. Samuel for his paper on "A Negative-Grid Triode Oscillator and Amplifier for Ultra-High Frequencies," which was published in the October, 1937, PROCEEDINGS.

Finances

A balance sheet showing comparative figures for 1937 and 1938 is given at the end of this report. In addition, Fig. 3 shows income and expenses for the life of the Institute.

Headquarters Staff

The headquarters staff has been reduced by one employee and now numbers twelve.

Deaths

The deaths of twelve members whose names are listed below were reported during the year.

Boehme, H. O.
Bond, E. F.
Cabot, Sewell
Casey, K. K. V.
Coleman, G. A.
Hill, C. A. R.
Natapoff, Gustave
Stoekle, E. R.
Thompson, J. H.
Toeplitz, Walter
Warner, J. C.
Wilkinson, A. E.

Acknowledgment

The activities of many Institute members are essential to its continued operation. The Board of Directors is responsible for the guiding policies and continuous supervision of its affairs and its many committees spend untold hours in putting these policies into practice and gathering data on which future operations will be based. The many dozens of members serving on the Board of Directors and our committees, deserve the sincere thanks of those who are unable to take an active part in the management and operation of the Institute.

Respectfully submitted,

Harold P. Westman

HAROLD P. WESTMAN
Secretary

The Institute of Radio Engineers, Inc.
Comparative Balance Sheet

December 31, 1938 and 1937

ASSETS	DECEMBER 31, 1938	DECEMBER 31, 1937	INCREASE DECREASE
Current Assets			
Cash	$21,108.69	$26,720.61	**$5,611.92**
Accounts Receivable—Current			
Dues	336.00	392.57	**56.57**
Advertising	358.00	349.69	8.31
Reprints	64.36	38.37	25.99
Inventory	7,285.79	9,238.93	**1,953.14**
Accrued Interest on Investments	285.28	345.00	**59.72**
Total Current Assets	$29,438.12	$37,085.17	**$7,647.05**
Investments—At Cost (Market Value December 31, 1938—$23,928.75)	46,922.12	37,200.37	9,721.75
Furniture and Fixtures After Reserve For Depreciation	2,131.76	2,278.53	**146.77**
Prepaid Expenses			
Unexpired Insurance	45.52	57.76	**12.24**
Stationery Inventory—Estimated	200.00	200.00	
Convention Expense	103.54	378.40	**274.86**
Total Assets	$78,841.06	$77,200.23	$1,640.83

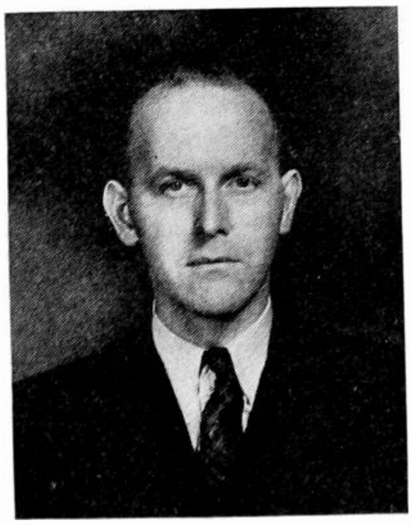
Liabilities and Surplus	DECEMBER 31, 1938	DECEMBER 31, 1937	INCREASE DECREASE
Accounts Payable	$ 2,699.48	$ 189.98	$2,509.50
Suspense	16.22	20.87	**4.65**
Advance Payments			
Dues	1,438.44	1,837.30	**398.86**
Subscriptions	4,035.86	4,119.35	**83.49**
Advertising	4.00		4.00
Total Liabilities	$ 8,194.00	$ 6,167.50	$2,026.50
Funds			
Morris Liebmann Memorial Fund Principal and Unexpended Income	10,077.87	10,077.87	
Associated Radio Manufacturers Fund	1,997.80	1,997.80	
Total Funds	$12,075.67	$12,075.67	
Surplus			
Balance—January 1	58,957.06	54,546.77	4,410.29
Add—Operating Profit or Loss for the Years	**385.67**	4,410.29	**4,795.96**
Surplus—December 31	58,571.39	58,957.06	**385.67**
Total Liabilities and Surplus	$78,841.06	$77,200.23	$1,640.83

Patterson and Ridgeway
Certified Public Accountants
74 Trinity Place
New York, New York

Contributors

W. M. Goodall

W. M. Goodall (A'29, M'37) was born on September 7, 1907, at Washington, D. C. He received the B.S. degree from California Institute of Technology in 1928, and since that time has been a member of the technical staff of Bell Telephone Laboratories.



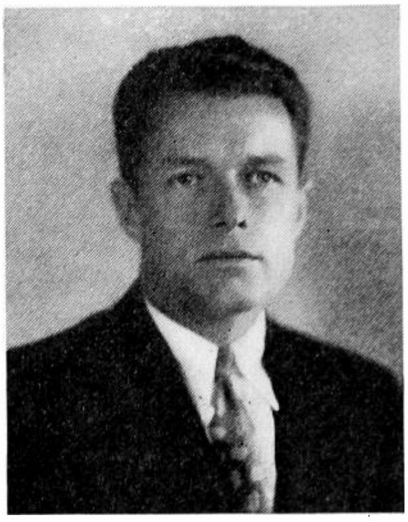
H. J. Hasbrouck

❖

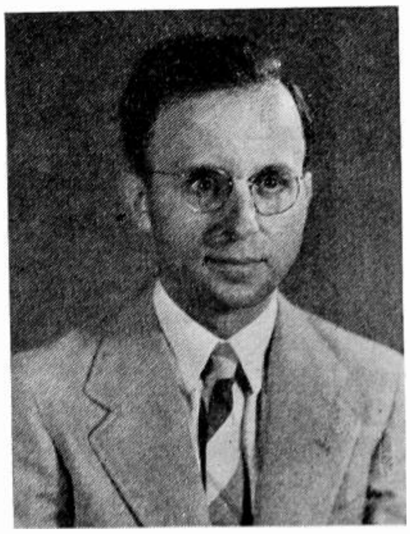
H. J. Hasbrouck, Jr., was born in New Rochelle, New York, on September 12, 1903, and was graduated from the Port Chester High School in 1921. He has been associated with the Municipal Broadcasting Station of Port Chester; Farrand Manufacturing Company; United States Tool Company; Seaboard Electric Manufacturing Company; United Research Corporation; Brunswick, Balke Callender Company; and Warner Brothers Pictures, Inc. Since 1935 he has been in the Photophone Advance Development department of the RCA Manufacturing Company.

❖

G. F. Lampkin (A '26) was born on April 2, 1905, at Wolcott, Indiana. From 1923 to 1927 he was a co-operative student engineer with the Allis-Chalmers Manufacturing Company and the Union Gas and Electric Company. He has been an amateur radio operator from 1924 to date. In 1927 Mr. Lampkin received his E.E. degree from the University of Cincinnati, and later was a Baldwin Fellow in electrical engineering, receiving his M.S. degree in 1928. In 1932 he established the Lampkin Laboratories in Bradenton, Florida.



G. F. Lampkin



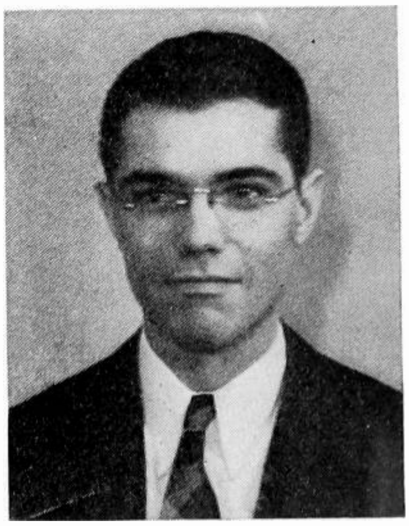
V. D. Landon

❖

Vernon D. Landon (A'27, M'29) was born on May 2, 1901. He attended Detroit Junior College. From 1922 to 1929 he was in charge of the radio-frequency laboratory of the Westinghouse Electric and Manufacturing Company. In 1931 he was assistant chief engineer of Radio Frequency Laboratories, and from 1931 to 1932 he was assistant chief engineer of Grigsby Grunow Company. Since 1932 he has served as an engineer in the Advance Development Section of the RCA Manufacturing Company, Victor Division.

❖

H. F. Mayer (A '36) was born on January 18, 1912, at Indianapolis, Indiana. He received the B.S. degree in electrical engineering in 1932 and the M.S. degree in 1933 from Purdue University. In 1933 Mr. Mayer was with P. R. Mallory and Company. From 1933 to 1934 he was a student engineer with the General Electric Company, and from 1934 to 1936 he was in their Vacuum Tube Engineering Department. Since 1936 he has been in their General Engineering Laboratory. He is an Associate member of Sigma Xi and a Member of Tau Beta Pi.



H. F. Mayer

G. R. Mezger

❖

G. Robert Mezger (A'37) was born in New York City on November 11, 1914. He received the E.E. degree from Rensselaer Polytechnic Institute in 1936. Since then he has been engaged in development work on cathode-ray oscillographs, associated apparatus, and television equipment with the Allen B. Du Mont Laboratories.

⁂

John D. Reid was born on March 18, 1907, at Morristown, New Jersey. From 1920 to 1923 he was an amateur radio operator, and from 1924 to 1926 attended the Wharton and Moore Schools at the University of Pennsylvania. Mr. Reid was a field engineer with Arcturus Radio Company from 1926 to 1927, and a special student at the University of Pennsylvania from 1928 to 1929. He was head of the radio engineering department of Norden Hauck, Inc., from 1930 to 1931, and since that date has been in the Special Apparatus, Receiver Design, and Advanced Development Sections of the RCA Manufacturing Company.


J. D. Reid


Samuel Sabaroff

⁂

Samuel Sabaroff was born in Philadelphia, Pennsylvania, on November 10, 1908. In 1931 he received the B.S. degree in electrical engineering from Drexel Institute and in 1937 of the M.S. degree from the University of Pennsylvania. From 1931 to 1932 he was in the reject-control and factory laboratory of the Philco Radio and Television Corporation. Since 1932 Mr. Sabaroff has been a transmitter engineer with the WCAU Broadcasting Company.


J. P. Schafer


M. J. O. Strutt

⁂

J. Peter Schafer (A'24, M'30) was born on October 29, 1897, at Brooklyn, New York. He received the B.S. degree in electrical engineering from Cooper Union in 1921 and the E.E. degree in 1925. He has been a member of the technical staff of the research department of the Western Electric Company and Bell Telephone Laboratories from 1915 to date being in the New York City laboratories from 1915 to 1922, the Rocky Point transatlantic radiotelephone station from 1922 to 1928, and the Deal radio laboratories from 1928 to date.


A. van der Ziel

⁂

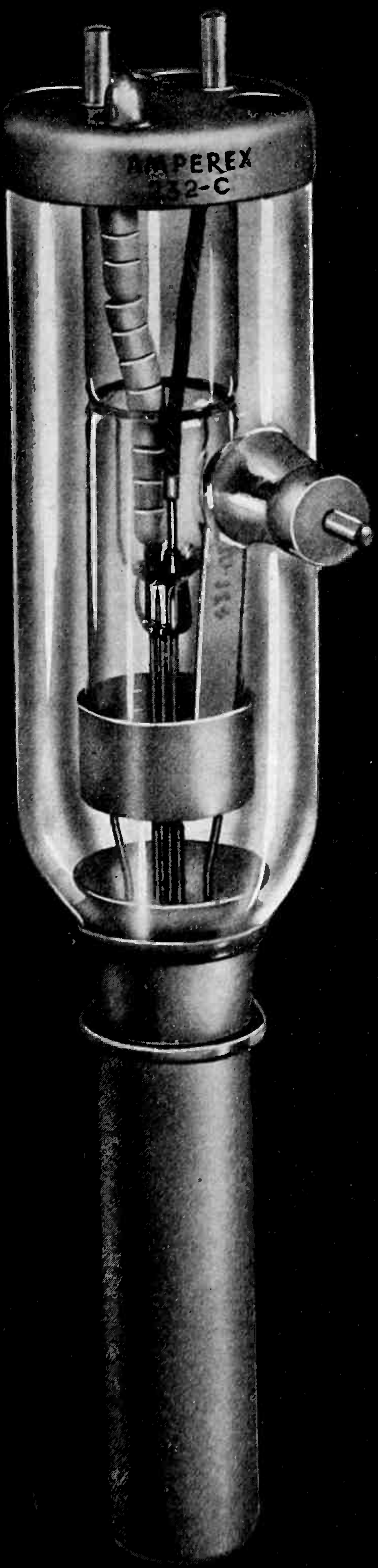
M. J. O. Strutt was born in 1903 at Java, Dutch East Indies. He studied at the University of Munich; the Institute of Technology at Munich; and the Institute of Technology at Delft. He was graduated from Munich in 1924 and Delft in 1926. From 1926 to 1927 he was an assistant in the Physics department, and in 1927 he received the degree of Doctor of Technical Science from Delft. Since 1927 he has been a member of the research staff of Philips' Incandescent Lamp Works, Ltd.

⁂

A van der Ziel was born at Zandeweer, Holland, on December 12, 1910. In 1934 he received the D.Sc. degree from the University of Groningen. Since 1934 he has been a member of the research staff of Natuurkundig Laboratorium der N. V. Philips' Gloeilampenfabrieken at Eindhoven, Holland. Mr. van der Ziel is a member of the American Physical Society.

⁂

For biographical sketches of T. R. Gilliland, S. S. Kirby, and Newbern Smith see the Proceedings for January, 1939.



the 220-C and 232-C

AMPEREX

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Similar to the new W.E. 342-A and 343-A

Have been operating satisfactorily in Broadcast transmitters where the original lighter filament types had proven both unsatisfactory in performance and in life duration.

Heavy rugged filaments of greatly increased emission capabilities is the outstanding feature of both of these Amperex Heavy Duty Types.

Effective shielding is provided for both the anode seal and grid support seals.

The grids are of the special Amperex design, where the cross wires are swedged into evenly and accurately spaced notches in the supporting rods. This exactness of spacing and absence of oxidation and brittleness in the Amperex mechanically constructed grids, results in uniform characteristics and trouble-proof operation.

220-C . . . $290 **232-C . . . $480**

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79 WASHINGTON STREET BROOKLYN, NEW YORK

DIVISION DE EXPORTACION: 100 VARICK STREET, NEW YORK, E. U. A. CABLEGRAMAS: "ARLAB".

Commercial Engineering Developments

These reports on engineering developments in the commercial field have been prepared solely on the basis of information received from the firms referred to in each item.

Sponsors of new developments are invited to submit descriptions on which future reports may be based. To be of greatest usefulness, these should summarize, with as much detail as is practical, the novel engineering features of the design. Address: Editor, Proceedings of the I.R.E., 330 West 42nd Street, New York, New York.

●

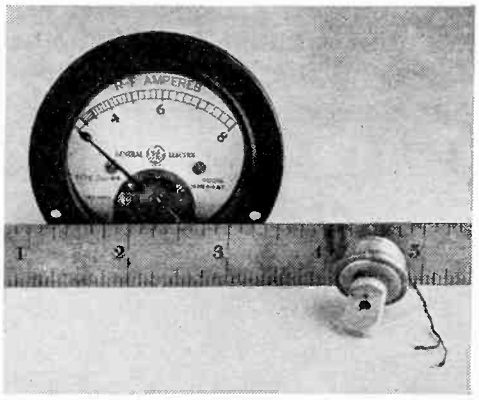
High-Frequency Thermocouple Instruments

In measuring currents at high frequencies by means of thermocouples, a number of complications arise which affect the accuracy of the measurement.

The most obvious of these, and one which had been given most discussion, is the error due to skin effect of the thermocouple heater. This is natural because the errors are relatively large and are amenable to at least a degree of calculation.

In addition, however, other effects arise which serve to impair the accuracy of the final measurement. Among these are the effect of external fields which are likely to be very pronounced in the case of high-frequency measurements where the measuring instrument is often located in close proximity to a generating source.

A third effect to which it has been necessary to give increased consideration is that of the measuring apparatus on the remainder of the circuit. When the frequencies in the neighborhood of 100 megacycles are considered, the inductance of the conventional straight heater thermocouple produces definitely undesirable effects, both from the standpoint of added circuit impedance and the fact that the instrument itself may be operating at a potential considerably above ground. The result of the latter consideration is that objectionable stray currents flow from the heater circuit to other portions of the instrument.



The thermocouple and its indicating instrument (Scale graduated in inches)

In an effort to reduce the combined total of the above effects to a minimum and secure more accurate indication, General Electric* engineers have designed a thermocouple ammeter which reduces these undesirable effects to considerably lower values than those found in the conventional construction.

To reduce the skin-effect over a wide range of current ratings, a very thin flat ribbon was used as a heater. This ribbon is doubled back upon itself and the inside surfaces are separated by a very thin strip of mica. This construction gives an acceptable value of skin-effect and has a definite advantage from the standpoint of low impedance.

The obvious way to minimize undesirable stray fields in the neighborhood of the instrument is to adopt a concentric arrangement of conductors as is done in many other branches of the radio-frequency art. In applying this arrangement to a high-frequency thermocouple, the current is led through an internal conductor suitably insulated by a bushing having low dielectric loss. One end of the small ribbon heater is brazed to the end of the central conductor, while the other end is affixed to a disk which forms the connecting member to the exterior tube wall. The leads from the thermo-junction are brought through a small opening in the end of the cylinder.

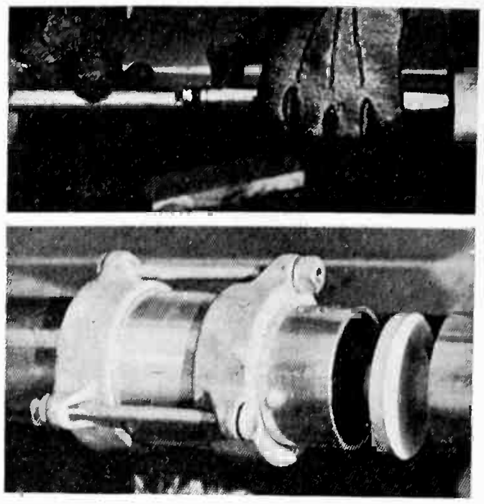
It will readily be appreciated that such a construction introduces a minimum of impedance in the circuit and difficulties due to parasitic flow of current through the instrument armature are eliminated to a large degree. To reduce further undesirable effects due to stray currents, the instrument employed is of the $2\frac{1}{2}$-inch size, rather than the more conventional $3\frac{1}{2}$-inch size. A thermoammeter rated at 8 amperes, employing such a construction, is shown in the photograph.

* General Electric Company, Schenectady, New York.

Aluminum Coaxial Transmission Line

A gas-filled coaxial transmission line using aluminum tubing instead of copper has been developed by Isolantite* in collaboration with engineers of the National Broadcasting Company and the Aluminum Company of America. A line of this type was recently installed to feed a new 470-foot vertical radiator at WTAM, the National Broadcasting Company's 50-kilowatt transmitter at Cleveland, Ohio.

The aluminum line was made possible by a coupling developed by the Raybould Coupling Company, which eliminates all need for soldering or welding and greatly simplifies the installation of the line. The coupling permits the forming of gas-tight joints of excellent electrical conductivity and high mechanical strength by a simple process of tightening nuts on the coupling.



Couplings for the aluminum coaxial line. *Above:* Ends of the inside tubes butt together over the coupling. When the tubes are rotated, the coupling expands, holding them firmly. *Below:* Coupling the outer conductor. Each end of the tubing butts against a face of the ceramic insulator. Then the coupling is slipped over it and tightened to make a conductive, gas-tight joint

In this coupling the pressure necessary to maintain a tight seal is applied axially, the bolts being parallel to the tubing, and is converted into radial pressure on the tubes. When the bolts are tightened, tapered surfaces exert upon metal banded rubber members pressures sufficient to cause the rubber to act as a fluid. This fluid pressure is transmitted to the metal bands which engage the ends of the tube sections. The metal bands are split to accommodate tube tolerances. Because the rubber acts as a fluid, practically all the pressure is transmitted to the metal bands, and is evenly distributed to give the fullest degree of engagement. The rubber also serves as the gas sealing medium.

The bands so enclose the rubber that there is no escape and no deterioration of the rubber. This method of connection gives a joint of higher tensile strength than is possible where rubber alone is used as the engaging medium.

For coupling sections of the inner tubes together a coupling of different design but employing the same principles is employed. The tubes butt together over the coupling so that there is no exposed portion to reduce the air space between the inner tube and the shield. Metal banded rubber rings compressed between cones expand to grip and pull the ends of the tubes together when they are rotated in opposite directions. Strap wrenches are necessary in order to apply torque sufficient to tighten the joint without marring the tubing.

The aluminum transmission line is expected to be comparable with a copper line in corrosion resistance and life. The tubing used is approximately the same diameter as the copper required for the same service, since the high-frequency current travels on the surface of the tubing. The resulting product weighs only one-third as much as a corresponding copper line.

* Isolantite, Incorporated, 233 Broadway, New York, New York.

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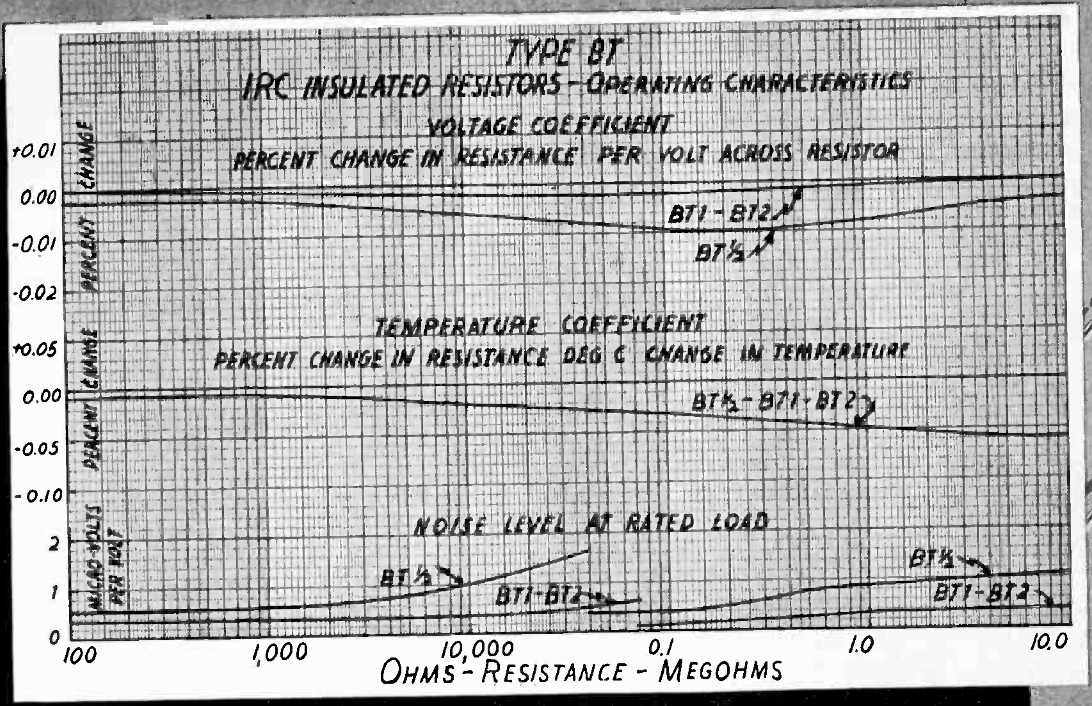

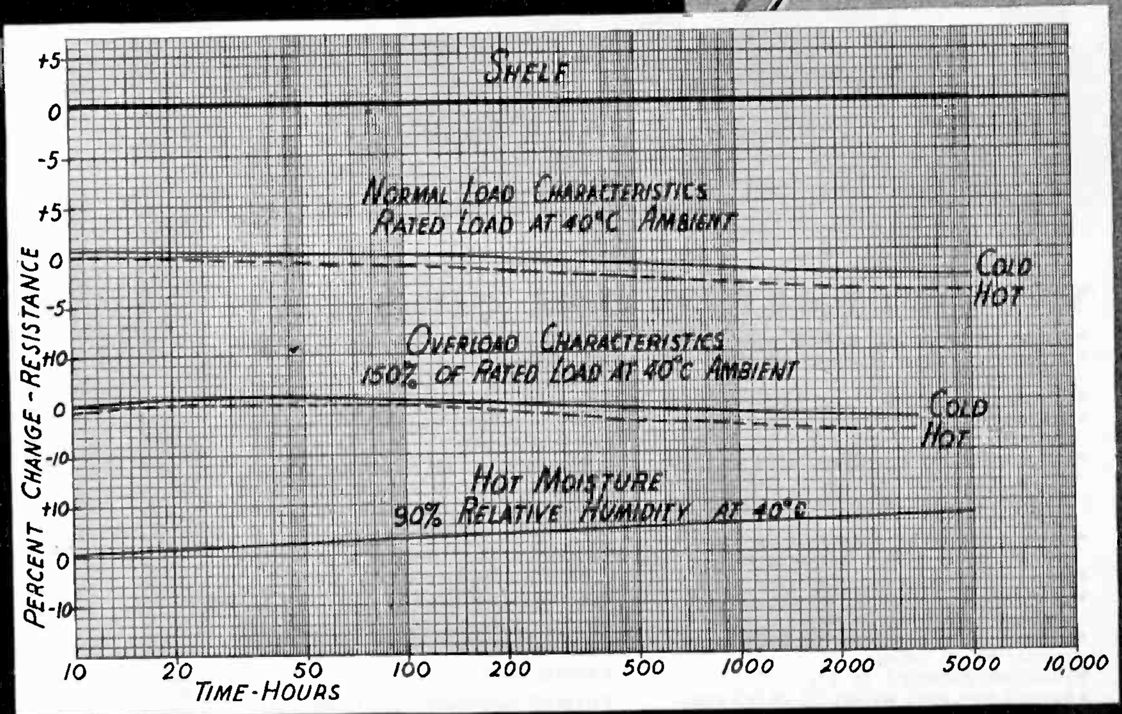

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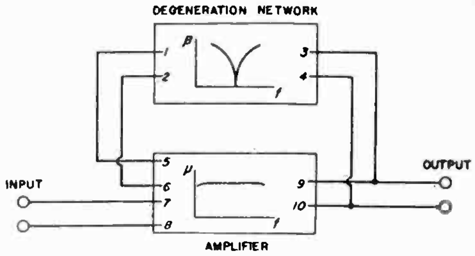
Degenerative Amplifier Applications

The inverse-feedback amplifier principle described by Scott* has been applied commercially in three instruments recently developed by the General Radio Company.†

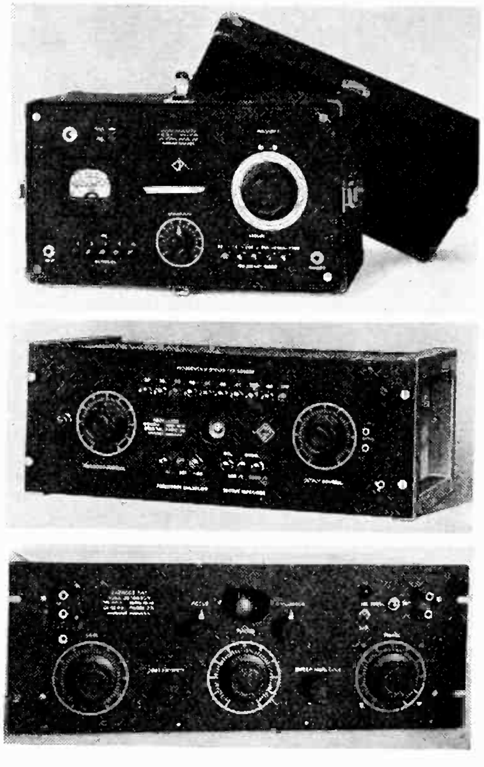
An analyzer, an audio-frequency oscillator, and a null detector for bridge measurements all make use of the accompanying schematic circuit. In it is shown an amplifier with a highly-selective resistance—capacitance network in its inverse-feedback circuit. The network balances to a null at a predetermined frequency at which the full gain of the amplifier is obtained; at all other frequencies the amplifier is highly degenerative.



The basic degenerative amplifier used in the three General Radio instruments consists of a wide-band amplifier with a narrow-band resistance-capacitance-tuned feed back circuit

The analyzer is intended for noise analysis work in conjunction with a sound-level meter and for electric-wave analysis over a voltage range of 100 to 1. The circuit is that of the general circuit with the addition of a meter across the output terminals.

The addition of direct regenerative coupling between the input and output in the general circuit makes the system self-oscillating. The oscillator, using this prin-



Three commercial instruments employing the basic degenerative amplifier circuit. *Top:* Sound analyzer. *Middle:* Oscillator. *Bottom:* Cathode-ray [bridge-] null indicator

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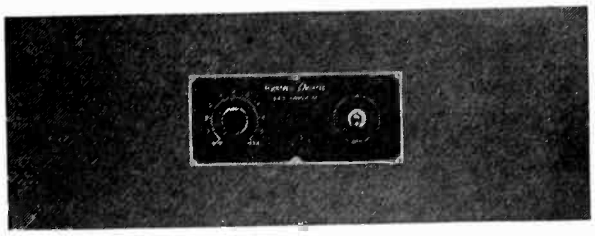
* H. H. Scott, "A new type of selective circuit and some applications," PROC. I.R.E., Vol. 26, pages 226–235; February, (1938).

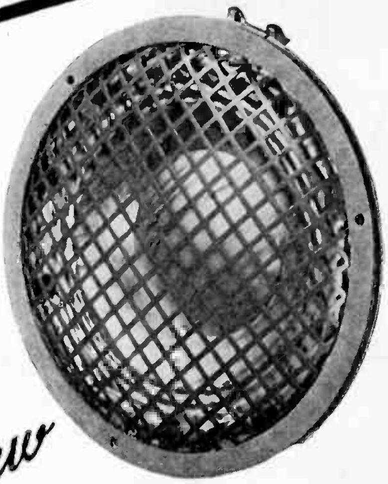
† General Radio Company, Cambridge, Massachusetts.

When these two get together,

You've got something!



94 TYPE AMPLIFIERS



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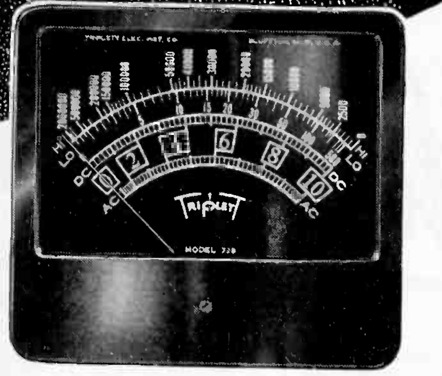
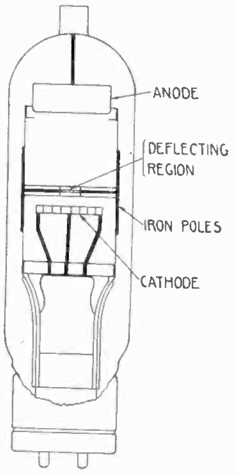


ciple, supplies 27 fixed frequencies between 20 and 15,000 cycles. The highly selective inverse feedback circuit permits excellent waveform to be obtained (total harmonic content less than 0.1 per cent of the fundamental voltage for the best adjustment) and a high degree of frequency stability.

A "cathode-ray null detector," an instrument for giving visual indication of balance in alternating-current impedance bridges, depends upon the selective-amplifier circuit for the frequency discrimination required to exclude noise and harmonics from the indicating circuit. The output of the bridge is applied through an 80-decibel inverse-feedback amplifier to the vertical deflecting plates of a one-inch cathode-ray tube. The bridge generator voltage is applied through an adjustable phase-shifting network to the horizontal plates. By observing the resulting pattern on the tube screen, the operator can secure independent indications of the effect of balancing either the reactive or resistive bridge controls separately as well as an indication of the magnitude and direction of the unbalance in either component.

Magnetic-Controlled Discharge Tube

A magnetically-controlled discharge tube for industrial and radio control purposes, the Permatron, was recently announced.* This tube performs a function similar to that of the thyratron except that control is obtained by an external magnet rather than a grid inside the tube. The magnetic field is employed to block conduction through the tube. When the field is reduced below a critical value, conduction starts and continues until the anode potential is removed or becomes negative. This type of control may be used as a "triggered" relay in direct-current circuits, or, with alternating magnetic fields, to give phase-shift control of output current.



Gas discharge tube for magnetic control

In addition to the applications in which the thyratron is now used it is expected that the Permatron will give rise to many new ones. These expectations are based on the facts that its control circuit may remain insulated from the tube and power circuit, the control is not affected by polarity of the magnetic field, control from direct-current may be obtained at any im-

---

* Raytheon Production Corporation, 55 Chapel Street, Newton, Massachusetts.

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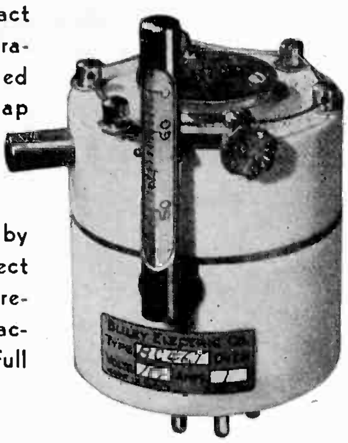

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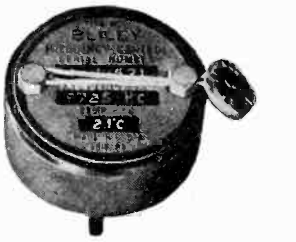

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pedance level by proper magnet coil design, and the controlling circuit is entirely linear and not affected by the non-linear operation of the tube. These features, to the extent that they remove old limitations, should allow development of many new circuits.

The Permatron may be used in grid control circuits but is designed with the primary object of obtaining high increasing magnetic sensitivity. The third electrode, called the "collector," contains a cylindrical section surrounding the discharge path. The magnetic field is applied across this section and performs its control by deflecting electrons which would normally proceed to the anode. These electrons represent a current microscopic in comparison to the normal anode current.

The most unusual features of design consist in making all conducting parts of non-magnetic materials with the exception of iron pole pieces used to conduct magnetic flux to the operating region from the spot on the bulb which is most convenient for application of the magnetic field. The manufacturers of this tube are also carrying out a program of research on circuit applications with the object of determining the best circuit fundamentals and to aid industrial exploitation of the unusual features of the tube.

Booklets, Catalogs and Pamphlets

The following commercial literature has been received by the Institute.

AIRCRAFT RADIO • • • *RCA Manufacturing Company, Inc., Camden, New Jersey. Bulletin, 8 pages, $8\frac{1}{2}\times 11$ inches.* Information on the "Location and Elimination of Engine Ignition Interference to Aircraft Radio Receivers."

BROADCAST TRANSMITTER • • • *Collins Radio Company, Cedar Rapids, Iowa, Bulletin. 4 pages, $8\frac{1}{2}\times 11$ inches.* Description of 20H and 20J 1000-watt broadcast transmitters.

COAXIAL CABLES • • • *Transducer Corporation, 30 Rockefeller Plaza, New York, New York. Bulletin CX. 10 pages, 9×12 inches.* Electrical and mechanical characteristics of flexible coaxial cables with resinoid or ceramic insulation.

COAXIAL LINES • • • *Isolantite, Inc., 233 Broadway, New York, New York. Bulletin 101-B, 8 pages, $8\frac{1}{2}\times 11$ inches.* Describes $\frac{7}{8}$-inch copper coaxial transmission lines and accessories.

COILS • • • *DX Radio Products Company, 1579 Milwaukee Avenue, Chicago, Illinois. Catalog, 22 pages, $8\frac{1}{2}\times 11$ inches.* Listings of radio-frequency coils.

CONDUCTIVITY BRIDGE • • • *Industrial Instruments, Inc., 162 West 23 Street, Bayonne, New Jersey. Bulletin RC-110, 4 pages, $8\frac{1}{2}\times 11$ inches.* Brief description of a 60-cycle bridge for measuring conductivity of electrolytes and resistance of solid conductors. Employs an amplifier and an "electric-eye" type tube as a null indicator.

DIRECT-CURRENT AMPLIFIER • • • *General Radio Company, 30 State Street, Cambridge A, Massachusetts. February, 1939,* "General Radio Experimenter," *12 pages, 6×9 inches.* Describes a 3-stage direct-current amplifier, intended primarily for improving the sensitivity of industrial recording instruments.

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Whatever your requirements may be, Cornell-Dubilier has or will design a capacitor to fill your needs. C-D engineers will be glad to assist you in finding the most economical solution to your capacitor problems. Catalog No. 160 on request. Your inquiries are invited.

DYKANOL FILTER CAPACITORS TYPE TLA

Compact high voltage filter capacitors for use with high fidelity public address amplifiers, power supplies for short wave transmitters and transceivers. Also ideally suited for television and facsimile receiver and transmitter applications. Hermetically sealed and filled with fireproof Dykanol. Will withstand transient voltages as well as high peak voltage surges. Available in a complete capacity range from 600 to 1,500 volts D.C. Completely described in Catalog No. 160.

Product of the world's largest manufacturers of capacitors.

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RCA 9-INCH *General Purpose* CATHODE-RAY OSCILLOGRAPH

TYPE 304-A

RCA has designed the type 304-A Cathode-Ray Oscillograph to meet the requirements of the experimental and research engineer for a high quality large screen oscillograph at a moderate price.

It is equipped with an RCA 914 High Vacuum Cathode-Ray tube employing the electrostatic deflection principle. The trace is very sharp and brilliant and permits extremely fast photographic recordings of transients.

The deflection amplifiers are essentially flat over a frequency response range of from 4 cycles to 100,000 cycles and will faithfully reproduce square waves as low as 10 cycle frequency.

An additional amplifier is provided for modulation of the cathode beam from an external timing source, and provides a very convenient means for establishing a time constant of the trace. All controls are symmetrically arranged on the front panel. The screen of the cathode-ray tube is protected by a shatter-proof lens.

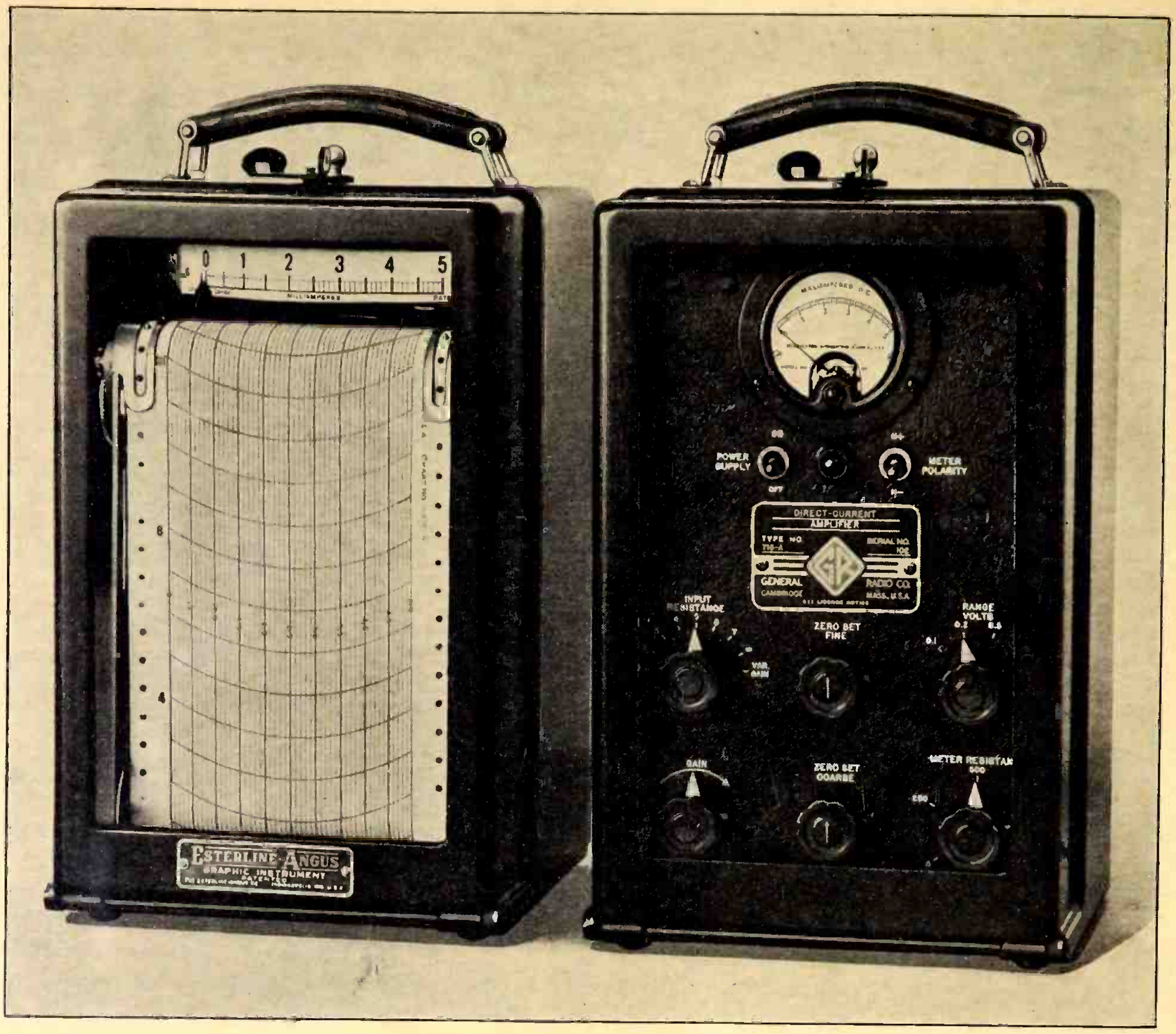
RCA HIGH GAIN *Low Frequency* PRE-AMPLIFIER

TYPE 9784

Here is an outstanding portable AC operated amplifier. It has a very high input resistance of 90 megohms, making it ideally suited for use with Piezo electric crystal generators and cathode-ray oscillographs.

RCA Manufacturing Co., Inc.

Engineering Products Division · Precision Test Equipment
Camden, New Jersey



NEW DIRECT-CURRENT AMPLIFIER

for Continuous Recording of Small Voltages and Currents

AFTER several years of research in circuit design and mechanical construction of a rugged and stable d-c amplifier for industrial recording, General Radio Company announces the Type 715-A Direct-Current Amplifier. This instrument successfully overcomes all of the obstacles which formerly have made the manufacture and use of an a-c operated direct-current amplifier impracticable.

The new amplifier is designed for use with a continuous recorder of the Esterline-Angus 5-milliampere type. It can be used with photo-electric and photronic cells, oxide rectifiers, resistance thermometers, frequency meters, sound-level meters and other such instruments to provide a continuous record of their operation.

The amplifier and recorder constitute a calibrated recording voltmeter. With known input resistances, a milliammeter or microammeter for recording d-c voltage and current variations can be obtained directly.

The new amplifier can be used in automatic control circuits where the amplifier output operates relays to control the original device which drives the amplifier.

It has high gain, operates from an a-c power line, is simple to use, is exceptionally stable with freedom from effects of ambient temperature and line voltage variations and has a wide range of built-in input voltage and resistance combinations.

This amplifier is supplied in either drawn steel case (illustrated) to match the Esterline-Angus recorder or in a walnut cabinet.

PRICES:
Type 715-AE Amplifier (Esterline-Angus Case)...$250.00
Type 715-AM Amplifier (Walnut Cabinet) $225.00

• ***Write for Bulletin 383 for Complete Information***

GENERAL RADIO COMPANY

Cambridge, Massachusetts

BRANCHES: NEW YORK AND LOS ANGELES

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