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Pacific Coast Convention

Los Angeles, Calif., August 27 and 28, 1940

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New York Meeting—Engineering Societies Building—April 3, 1940

33 West 39th Street, New York, N. Y.

SECTION MEETINGS

CLEVELAND
April 25

ATLANTA April 16	**DETROIT** April 19	**PHILADELPHIA** April 4
BALTIMORE April 19	**LOS ANGELES** April 16	**PITTSBURGH** April 16
BUFFALO-NIAGARA April 3	**MONTREAL** April 10	**WASHINGTON** April 8

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WASHINGTON—Chairman, L. C. Young; Secretary, E. M. Webster, Federal Communications Commission, Rm. 5319, New Post Office Bldg., Washington, D. C.

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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 1800 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 received 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-three cities in the United States, Canada, and Argentina 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, the Pacific Coast Convention, which is held each year during the summer months and is supervised by a joint committee of our four Pacific Coast sections, and the Annual Convention, which will be held in New York City during January.

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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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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Radio Progress During 1939

THE year 1939 presented an unusual degree of progress in nearly all branches of science. In radio, progress was particularly marked, and the year was probably the outstanding one of the last two decades. The year was unusual in that great progress was effected in all aspects of the art, in the scientific branch, in engineering matters, and in practical public-service innovations.

On the scientific front, progress in investigation of wave propagation was especially noteworthy, and the resulting increased knowledge brought about improvement in the ability to select frequencies most effective in long-distance transmission. Much new knowledge of an immediately useful sort was acquired in the relatively new field of ultra-high-frequency propagation, and the National Bureau of Standards began the service of issuing monthly predictions of maximum usable frequencies.

Many new instrumentalities of much practical use were made available. New tubes and devices for the handling of ultra-high frequencies, noise-measuring instruments, numerous new electronic devices, new insulation materials, and measurements of the hearing capacities of three quarters of a million people, were among the noteworthy items and indicate the wide range of contributions to the field. During the year the National Bureau of Standards began another useful public service by transmitting continuously a radio carrier frequency of 5 megacycles modulated with the standard musical pitch of "A440." This service is of great benefit to the musical and broadcast industries by making possible the pitch standardization of musical instruments.

Three new broadcast services were introduced to the public during the year. These were television, facsimile, and ultra-high-frequency sound broadcasting with frequency-modulated waves. In each of these services several stations began regular program operation and receivers were placed on the market for sale to the public. Any single year witnessing the introduction of one important new public service is noteworthy so that the year 1939 was especially remarkable because it saw the introduction of three important new public services.

In commercial facsimile communication, many improvements in technique were introduced during the year, with consequent great improvement in the quality of picture transmission by radio. In addition, high-quality picture transmission by high-speed cable between New York and London was initiated early in the year.

In the home broadcast-receiver field, the performance in the United States was record-breaking. The number of receiving sets and the number of vacuum tubes manufactured during the year was about 50 per cent greater than in 1938. About 9,000,000 receivers, and 100,000,000 receiving vacuum tubes were produced in the United States. There was a marked increase in the use of lightweight dry-battery-operated portable receivers, radio-phonograph combinations, and attachments for home recording. These items, in total, represent a very substantial increase in the home utilization of radio and its associated instrumentalities.

The foregoing summary is based on the information compiled by the Institute's technical committees and reported by them in the following pages. The summary was prepared by the 1939 Annual Review Committee, the personnel of which follows:

A. F. Van Dyck, Chairman

E. K. Cohan	*H. S. Knowles*
J. H. Dellinger	*E. G. Ports*
W. G. H. Finch	*H. M. Turner*
D. E. Foster	*P. T. Weeks*
Keith Henney	*L. E. Whittemore*

PART I—ELECTROACOUSTICS*

Loud Speakers—Microphones—Electromechanical Devices—Room Acoustics—Measuring Apparatus and Techniques—Speech and Hearing

Loud Speakers

No fundamentally new types of loud speakers were reported during 1939. The moving-coil direct-radiator type continued its domination of radio applications. Improvements were made which extend the frequency range, diminish nonlinear distortion, and improve the spatial distribution at high frequencies.

A horn-type loud-speaker unit utilizing an annular or ring-shaped diaphragm with high flexural stiffness, was made available. The lowest flexural resonant frequency substantially exceeds that of a dome-shaped diaphragm of equal area. The outlet location is so chosen as to maintain uniform radiation resistance up to a relatively high frequency.

A new cellular horn has rigid medial partitions attached to the cell walls through resilient damping material, to stiffen the cell walls, dampen their mechanical modes, and eliminate approximately half the transverse acoustic modes. The total radiation and polar characteristic of a cellular horn depend on the relative transit times of the sound waves through the passages. In this horn the passages are so constructed

* Decimal classification: 621.385.97.

that the transit time is controlled without changing their physical length.

Uniform coverage over a wide horizontal angle was achieved in a single-channel horn.[1] A throat section connects at right angles with a mouth section which subtends a constant horizontal angle and has a suitably chosen vertical flare.

Frequency modulation and television revived interest in inexpensive wide-range loud speakers. Improvements in the design of curvilinear diaphragms and their suspensions made possible the production of several single-diaphragm units[2] meeting these requirements.

Refinements in single-voice-coil, multiple-cone loud speakers were also reported.[3]

Further investigations into nonuniformities of the magnetic field in the air gap of a moving-coil loud speaker were reported[4,5] and good agreement between experimentally determined and calculated values shown.

An experimental study of European output tubes employing loud-speaker loads was reported.[6] Tests were made of pentodes with negative feedback sufficient to provide source resistance and resulting damping equivalent to that for a triode. Under these conditions pentodes proved to be superior as regards power sensitivity, distortion, and effect of reactive components of the normal loud-speaker impedance.

There was made commercially available a compact dual-speaker system which consists of a small direct-radiator high-frequency speaker mounted coaxially within the hollow of the cone of a low-frequency unit. The size and position of the high-frequency unit result in a wide-angle polar response and wide-range reproduction with apparent unit source.

Microphones

No radically new types of microphones appeared during 1939, more attention being paid to applications.

The frequency spectra of impulsive sound sources, when placed in free space, pressure chambers, and exponential horns, were investigated.[7] These sources were used in the calibration of microphones, the results agreeing to within ± 1 decibel with those obtained by conventional means.

Electromechanical Devices

Investigations of the physical properties of piezoelectric crystals were continued. One research[8] measured the elastic, electric, and piezoelectric constants by determining, at low field strengths, the resonant frequency and impedance of vibrating Rochelle salts. It was shown that the lowest resonant frequency of the crystal is considerably below the natural mechanical resonant frequency of the piezoelectric crystal. If piezoelectric stress is assumed proportional to the charge density rather than the potential gradient as was usually assumed, then agreement appears between theory and experiment. Other researches dealt with the specific heat of the crystals to ascertain whether anomalies exist[9,10] but agreement between different investigators is lacking.

An inexpensive radio-phonograph combination incorporating a simplified recording mechanism for home use has been offered by one radio receiver manufacturer. Coated-paper record blanks are used, and recordings can be made from either microphone or radio input with immediate playback through the regular phonograph channel.[11]

Recording on disks for immediate playback continued to be based largely on experience rather than theory, with a fuller appreciation of the many precautions[12] necessary. The effects of pickup, character of track modulation, and ear response on scratch were investigated.[13]

Recording on magnetic tapes received much attention, with continued improvement in convenience and response.[14]

The effect of transient elastic deformation of lateral-cut phonograph-record grooves was investigated[15] from the viewpoints of tracking and distortion.

Studies of piezoelectric crystals as elements of electroacoustic devices were made to determine design characteristics of the crystal and matching amplifier.[16,17]

Room Acoustics

The problems encountered in architectural acoustics are so complex that most of the advances were of an empirical nature. However, the fresh viewpoint of recent theoretical work gave every indication of aiding

[1] "Loudspeaker," *Electronics*, vol. 12, p. 68; December, (1939).

[2] G. W. Fyler and J. A. Worcester, Jr., "A noise-free radio receiver," *Gen. Elec. Rev.*, vol. 42, p. 309; July, (1939).

[3] "Voigt 'light coil twin' loudspeaker," *Wireless World*, vol. 44, p. 223; March 9, (1939).

[4] V. V. Furdeev, N. K. Mikheeva, and B. S. Grigor'ev, "Nonlinear distortion electrodynamic loud speaker," *Izvestiya Elektroprom. Slab. Toka*, no. 2, pp. 25–38; (1939).

[5] W. Reinhard, "Inhomogeneity of the magnetic fields of dynamic loud speaker," *Akust. Zeit.*, vol. 4, pp. 137–141; March, (1939).

[6] A. J. Heins van der Ven, "Output stage distortion," *Wireless Eng.*, vol. 16, pp. 383–390; August, (1939), and vol. 16, pp. 444–452; September, (1939).

[7] W. Weber, "The sound spectra of sparks and pistol shots with reference to their application to electroacoustic measurement technique," *Akust. Zeit.*, vol. 4, pp. 373–391; November, (1939).

[8] W. P. Mason, "A dynamic measurement of the elastic, electric and piezo-electric constants of Rochelle salt," *Phys. Rev.*, vol. 55, pp. 775–789; April 15, (1939).

[9] W. Bantle and P. Scherrer, "Anomaly of the specific heat of potassium dihydrogen phosphate at the upper Curie point," *Nature*, vol. 143, p. 980; June 10, (1939).

[10] A. J. C. Wilson, "The heat capacity of Rochelle salt between −30° and +30° C.," *Phys. Rev.*, vol. 54, pp. 1103–1109; December 15, (1938).

[11] "Recordio," *Radio and Telev. Ret.*, vol. 24, p. 55; October, (1939).

[12] C. J. Lebel, "Disc cutting problems," *Electronics*, vol. 12, pp. 17–19; December, (1939).

[13] M. G. Scroggie, "Gramophone record scratch," *Wireless World*, vol. 46, pp. 3–7; November, (1939).

[14] B. Mueller-Ernesti, "The magnetophone," *Funktech. Monatshefte*, no. 5, pp. 151–154; May, (1939).

[15] F. V. Hunt and J. A. Pierce, "Stylus-groove relations and their influence on phonograph reproducer design." Presented, November, 1939, meeting, Acoustical Society of America, Iowa City, Iowa.

[16] P. Beerwald and H. Keller, "Piezoelectric crystal elements for electroacoustical purposes," *Funktech. Monatshefte*, no. 11, pp. 345–348; November, (1938), and pp. 97–100; April, (1939).

[17] C. Crescini, "Piezoelectricity in acoustics," *Radio e Televisione*, vol. 3, pp. 51–61; January, (1939).

progress by beginning to explain many of the effects encountered in practice.

The room problem received extensive theoretical treatment in which the normal acoustic impedance of the boundaries was used to determine the modes of free vibration.[18,19] The pressure variation in the standing waves between walls, one of which has infinite impedance, gives information applicable to live-end—dead-end studio construction.

Information pertinent to the boundaries was obtained by steady-state transmission measurements[20] between source and receiver in a model room. The width of the resonance curve at the half-intensity points was shown to be a measure of the total absorption for a given mode of vibration.

Methods for the computation of sound-pressure decay were presented for simple configurations of source, treated room, and detector.[21] Results agreed very well with measured decay curves using warble tones and an automatic recorder. An important feature is the weighting of the normal modes of vibration according to their directions.[22]

Isobaric plots of the sound field in model rooms of high wall impedance[23] show the effects of sloping walls and coupled spaces and the existence, in rooms of irregular shape, of well-defined standing-wave patterns.

The use of an enclosure of moderate size to study the decay of isolated normal modes[24] was reported. Good agreement was obtained between damping coefficients obtained from reverberation times and those computed by normal impedance measurements.

A study of the absorption coefficients of materials by a direct measurement of reflection in free space was made,[25] and comparisons with theoretical values and the usual standing-wave method values showed good agreement.

A sound source for space-acoustic measurement was developed providing a plurality of equiamplitude tones[26] spaced equally in frequency over a frequency band. The tones, derived from disk records, have a constant ratio of band width to mean frequency.

More work was done with resonant absorbers consisting of resistive as well as reactive elements.[27] A device using this principle was constructed for determining absorption coefficients by the substitution method.[28]

Measuring Apparatus and Techniques

The technique of square-wave testing,[29] given a great impetus by television, has important application in the testing of electrical and electroacoustic apparatus. There was announced a generator[30] for this purpose, in which the voltage change takes place within 0.001 cycle.

An optical harmonic analyzer was constructed[31] which uses a variable-area recording of the sound to be analyzed. Variable-density masks of the desired harmonics are superimposed on the original and the combination scanned for maximum and minimum light transmission to obtain amplitude and phase.

The German Acoustics Committee made proposals[32] to the International Standardization Association (I.S.A.) regarding specifications for microphone and loud-speaker rating and testing, for an international standard of pitch, and for recording and playback equipment.

The need for a standard of musical pitch has been demonstrated by a series of measurements[33] on "A440" taken during concerts broadcast from four European countries. The average pitch of each of the various groups varied markedly, and small deviations were noted during a performance. The continuous broadcast of "A440" at a carrier frequency of 5 megacycles was inaugurated by the National Bureau of Standards.[34]

Apparatus for producing artificial reverberation was developed. In one type the signal is magnetically recorded on a moving tape from which a number of time-displaced pickup heads feed the energy, through adjustable volume controls, back into the transmission line.[35] In another, delay and decay are obtained by impressing signal-modulated radiant energy from a mercury-vapor source on the phosphor-coated rim of a rotating wheel.[36] A third type utilizes a mechanical transmission line of interconnected helical springs, with various values of impedance and time of trans-

[18] P. M. Morse, "Some aspects of the theory of room acoustics," *Jour. Acous. Soc. Amer.* vol. 11, pp. 56–66; July, (1939).
[19] P. M. Morse, "Transmission of sound inside pipes," *Jour. Acous. Soc. Amer.*, vol. 11, pp. 205–211; October, (1939).
[20] F. V. Hunt, "Investigation of room acoustics by steady-state transmission measurements," *Jour. Acous. Soc. Amer.*, vol. 10, pp. 216–227; January, (1939).
[21] F. V. Hunt, L. L. Beranek, and D.-Y. Maa, "Analysis of sound decay in rectangular rooms," *Jour. Acous. Soc. Amer.*, vol. 11, pp. 80–94; July, (1939).
[22] D.-Y. Maa, "Distributions of eigentones in a rectangular chamber at low frequency range," *Jour. Acous. Soc. Amer.*, vol. 10, pp. 235–238; January, (1939).
[23] R. H. Bolt, "Normal modes of vibration in room acoustics: Experimental investigations in non-rectangular enclosures," *Jour. Acous. Soc. Amer.*, vol. 11, pp. 184–197; October, (1939).
[24] N. B. Bhatt, "Effect of an absorbing wall on the decay of normal frequencies," *Jour. Acous. Soc. Amer.*, vol. 11, pp. 67–73; July, (1939).
[25] F. J. Willig, "Comparison of sound absorption coefficients obtained by different methods," *Jour. Acous. Soc. Amer.*, vol. 10, pp. 293–299; January, (1939).
[26] W. L. Barrow, "The multitone," *Jour. Acous. Soc. Amer.*, vol. 10, pp. 275–279; April, (1939).
[27] W. Willms, "On sound absorption with the aid of damped resonators," *Akust. Zeit.*, vol. 4, pp. 29–32; January, (1939).
[28] K. Schuster and W. Stohr, "Design and properties of an adjustable comparison impedance," *Akust. Zeit.*, vol. 4, pp. 253–260; July, (1939).
[29] G. Swift, "Amplifier testing by means of square waves," *Communications*, vol. 19, pp. 22–26, 52; February, (1939).
[30] L. B. Arguimbau, "A demonstration of audio testing with square waves," *Electronics*, vol. 12, pp. 23–24; December, (1939). (Summary only.)
[31] H. C. Montgomery, "Optical curve analysis," *Bell Lab. Rec.*, vol. 18, pp. 28–30; September, (1939).
[32] "Communication from the German Acoustics Committee," *Akust. Zeit.*, vol. 4, pp. 62–80; January, (1939).
[33] B. van der Pol and C. C. J. Addink, "The pitch of musical instruments and orchestras," *Philips Tech. Rev.*, vol. 4, pp. 205–210; July, (1939).
[34] "WWV schedules," *QST*, vol. 24, p. 25; January, (1940).
[35] S. K. Wolff, "Artificially controlled reverberation," *Jour. Soc. Mot. Pic. Eng.*, vol. 32, pp. 390–397; April, (1939).
[36] P. C. Goldmark and P. S. Hendricks, "Synthetic reverberation," Proc. I.R.E., vol. 27, pp. 747–752; December, (1939).

mission. A moving-coil motor drives the line, and the delayed signal, with its multiple and nonuniform reflections, is picked up by a piezoelectric receiver.

For investigating microphone distortion a standing-wave resonance system was described[37] that produces a high-pressure sound field in which a given harmonic has been eliminated. It consists of a long, heavy-walled iron pipe with a dynamic loud speaker at one end and a movable iron piston at the other. Harmonic attenuation factors of 68 to 1 and higher (on a pressure basis) are obtained, hence the sound field is free of the unwanted harmonic to within a few hundredths of one per cent with three per cent harmonic in the speaker-input voltage.

Speech and Hearing

Additional data concerning speech characteristics became available. A study of sound pressure in the neighborhood of a speaker's head[38] revealed that equalization of microphone circuits to correct for this variation is unnecessary for angles between +90 and −45 degrees in the vertical plane and up to horizontal angles of 75 degrees. Further information permits equalization at extreme angles. These data permitted the calculation of the average spectra of voice power for men and women.[39,40]

Important additions to our statistical knowledge of hearing ability resulted from measurements on a large representative sample of people obtained under controlled conditions.[41,42] In one study, tests for the acuity of hearing for both pure tones and spoken words were made on half a million persons at the New York and the San Francisco World's Fairs.[43,44] Preliminary conclusions indicate hearing deficiencies sufficiently common to warrant their consideration in the design of reproducing equipment.

Threshold variations in the frequency band width which the ear just perceives in speech transmission were reported.[45] By progressively changing the cutoff frequency of low- or high-pass filters, the ear distinguishes approximately 30 stages of band-width variation; only some of these are approximately logarithmic frequency increments.

A binaural hearing aid has been developed employing an artificial head containing two microphones at the ear positions. The transmission of each channel is adjusted to the individual ear.[46] Another hearing aid has been introduced using an improved bone-conduction receiver[47] with a new type of spring-suspension design giving increased efficiency, extended frequency response, and a sharp high-frequency cutoff.

The asymmetry of the wave form of masculine speech has been used to permit "150 per cent modulation" by so connecting the microphone to the transmitter as to make the larger peaks correspond to positive modulation.[48]

Basic studies of speech sounds led to the construction of devices for synthesizing speech. In one instance, an instrument analyzes the pitch and spectral distribution of a speaker's words and by means of low-frequency control currents containing none of the original frequencies, synthesizes speech from a combination of buzz- and hiss-type sounds.[49,50] Another version of this instrument was constructed for demonstration purposes in which arbitrary speech sounds were obtained from the same components as above but controlled manually by a skilled operator.[51]

As a factor in stimulating audience reaction in the theater, increased use is being made of supplementary sound controlled by electronic means.[52] Experiments were carried on and methods developed by which the entire frequency and intensity range to which the ear responds may be used to establish locale, atmosphere, and mood.

A number of developments reported during 1938 had their first formal publication in 1939.[53–56]

This report was prepared by the 1939 Technical Committee on Electroacoustics of the Institute of Radio Engineers, the personnel of which follows:

H. S. Knowles, Chairman

L. B. Blaylock	*Knox McIlwain*	*George Nixon*	*H. F. Olson*
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[37] W. D. Phelps, "A sound source for investigating microphone distortion," *Jour. Acous. Soc. Amer.*, vol. 11, pp. 219–221; October, (1939).

[38] H. K. Dunn and D. W. Farnsworth, "Exploration of pressure field around the human head during speech," *Jour. Acous. Soc. Amer.*, vol. 10, no. 3, p. 184; January, (1939).

[39] H. K. Dunn and S. D. White, "Statistical measurements on conversational speech," *Jour. Acous. Soc. Amer.*, vol. 11, pp. 278–288; January, (1940).

[40] H. Kahl, "Sound-level distribution recorder," *Bell Lab. Rec.*, vol. 17, pp. 254–256; April, (1939).

[41] W. C. Beasley, "The prevalence of nerve deafness in the population" Presented, November, 1939, meeting, Acoustical Society of America, Iowa City, Iowa.

[42] W. C. Beasley, "National health survey, preliminary report, hearing-study series," (a series of 7 pamphlets) National Institute of Health, United States Public Health Service, Washington, D. C.

[43] H. C. Montgomery, "Hearing survey at the New York and San Francisco World's Fairs," *Jour. Acous. Soc. Amer.*, vol. 11, p. 378, January, (1940). (Abstract only.)

[44] H. C. Montgomery, "Analysis of World's Fairs' hearing tests," *Bell Lab. Rec.*, vol. 18, pp. 98–103; December, (1939).

[45] E. Schafer, "The audibility of variations in frequency band in speech transmission," *Elek. Nach. Tech.*, vol. 15, pp. 237–240; August, (1938).

[46] K. de Boer and R. Vermeulen, "On improvement of defective hearing," *Philips Tech. Rev.*, (English Edition), vol. 4, pp. 316–320; November, (1939).

[47] M. S. Hawley, "The 710A bone-conduction receiver," *Bell Lab. Rec.*, vol. 18, pp. 12–14; September, (1939).

[48] J. L. Hathaway, "Effect of microphone polarity on percentage modulation," *Electronics*, vol. 12, pp. 28–29, 51; October, (1939).

[49] H. Dudley, "Automatic synthesis of speech," *Nat. Acad. Sci. Proc.*, vol. 25, pp. 377–383; July, (1939).

[50] H. Dudley, "Remaking speech," *Jour. Acous. Soc. Amer.*, vol. 11, pp. 169–177; October, (1939).

[51] H. Dudley, Reisz, and Watkins, "Synthetic speech," *Jour. Frank. Inst.*, vol. 227, pp. 739–764; June, (1939).

[52] H. Burris-Mayer, "Sound in the theatre," *Jour. Acous. Soc. Amer.*, vol. 11, pp. 346–351; January, (1940).

[53] H. F. Olson, "Multiple coil, multiple cone loud speakers," *Jour. Acous. Soc. Amer.*, vol. 10, pp. 305–312; April, (1939). (See reference 7 in 1938 report.)

[54] Frank Massa, "Effect of physical size on the directional response characteristics of unidirectional and pressure gradient microphones," *Jour. Acous. Soc. Amer.*, vol. 10, pp. 173–179; January, (1939). (See reference 17 in 1938 report.)

[55] H. F. Olson, "Line microphones," Proc. I.R.E., vol. 27, pp. 438–446; July, (1939). (See reference 18 in 1938 report.)

[56] H. J. Hasbrouck, "Lateral disk recording for immediate playback with extended frequency range," Proc. I.R.E., vol. 27, pp. 184–187; March, (1939). (See reference 26 in 1938 report.)

PART II—ELECTRONICS*

Cathode-Ray and Television Tubes—Ultra-High-Frequency Tubes—Receiving Tubes—Transmitting Tubes—Gas Tubes—Photoelectric Devices

Cathode-Ray and Television Tubes

Television pickup tubes of the iconoscope type were made more sensitive and with a more sharply focused beam. A tube which attains high storage efficiency and freedom from spurious signals through the use of a scanning beam composed of low-velocity electrons was announced.[1,2] Further improvements in tubes which use a picture-storage grid to control the passage of scanning electrons[3] and in tubes which use secondary-emission amplification of an electron image,[4,5] took place. Theoretical work showed the possibility of attaining a large increase in pickup-tube sensitivity by using repeated multiplication of an electron image of the scene to be transmitted.[6] New forms of pickup tubes which operate with beams of high-velocity electrons[4] or make use of change in capacitance resulting from illumination were developed.[7]

Direct-viewing television picture tubes with larger deflection angles than heretofore were made available commercially. These are shorter tubes and have better spot-size characteristics at the cost of increased scanning-power requirements and greater susceptibility to spot distortion at the picture edge. Wider use is being made of magnetic lenses for focusing the beam.[8] A method of avoiding the ion-spot discoloration of the screen by separation of the ions from the electrons by means of a constant transverse magnetic deflecting field appeared.[9] The possibility of increasing the beam voltage without proportionately decreasing the deflection sensitivity by means of beam acceleration after deflection received both theoretical and experimental study,[10,11] Such tubes have been made available. Geometrical distortion of the picture shape resulting from bulb curvature has been avoided in some tubes by using a flat screen.[9] In one type of tube the screen has a rectangular shape enabling more of the screen area to be used for the picture.[12] The design of magnetic-deflection coils has received attention.[13]

A projected picture, 12 by 15 feet, having improved brightness was demonstrated to motion-picture audiences.[14] A projection tube in which the fluorescent screen is deposited on the inner surface of a metal wall, the outer surface being exposed for direct air-cooling,[12] was developed for use with home television receivers. Theoretical and experimental investigations demonstrated the possibility of using a cathode-ray beam to control the light transmission of a screen.[15,16] In one form of tube, zinc-blende crystals are flooded with polarized light, and the transmitted light is focused on the projection screen.

Published investigations in the field of electron optics include a mathematical analysis of the electron-lens field,[17] calculations for the focusing of high-velocity electrons,[18,19] analysis of the acceleration of electrons after deflection,[11] and calculation of aperture errors.[20]

Continued analyses of the possibilities and limitations of the electron microscope have led to published results dealing with chromatic errors[21,22] and resolving power.[23,24] The raster or scanning-type[25] and the shadow-type[26] microscope were described and their relative merits discussed.[27]

* Decimal classification: R330×621.375.1.

[1] Albert Rose and Harley Iams, "Television pickup tubes using low-velocity electron-beam scanning," Proc. I.R.E., vol. 27, pp. 547–555; September, (1939).

[2] "Orthicon," *Electronics*, vol. 12, pp. 11–14, 58–59; July, (1939).

[3] Knox McIlwain, "Survey of television pick-up devices," *Jour. App. Phys.*, vol. 10, pp. 432–442; July, (1939).

[4] J. D. McGee and H. G. Lubszynski, "E.M.I. cathode-ray television transmission," *Jour. I.E.E.* (London), vol. 84, pp. 468–475; April, (1939).

[5] M. Knoll, "Cathode-ray television tubes," *Telefunken Hausmitteilungen*, 20th year, pp. 65–79, July, (1939).

[6] H. A. Finke "A television pickup tube," Proc. I.R.E., vol. 27, pp. 144–147; February, (1939).

[7] M. Knoll and R. Thiele, "Capacity-modulated cathode-ray scanning tubes," *Teleg.- Fern.- und Funk-Tech.*, (Supplement), vol. 27, pp. 538–540; November, (1938).

[8] "The wireless exhibition, 1939; A technical survey," *Wireless Eng.*, vol. 16, p. 510; October, (1939).

[9] "Philco demonstrates improved picture tube," *Radio and Tel. Weekly*, vol. 47, p. 6; June 21, (1939).

[10] E. Schwartz, "On the present position of the problem of post-deflection acceleration in cathode-ray tubes," *Fernseh A. G.*, vol. 1, pp. 19–23; December, (1938).

[11] Rogowski and Thielen, "Post-acceleration in cathode-ray tubes," *Arch. für. Elektrotech.*, vol. 33, pp. 411–417; June 14, (1939).

[12] R. Moller and G. Schubert, "The further development of our receiver and picture-viewing devices for 1939," *Fernseh A. G.*, vol. 1, pp. 153–161; August, (1939).

[13] H. Bahring, "The deflection of the electron ray in the cathode-ray tube by magnetic fields produced by coils," *Fernseh A. G.*, vol. 1, pp. 15–19; December, (1938).

[14] "Baird cinema equipment," *Television*, vol. 12, p. 199; April, (1939).

[15] M. von Ardenne, "Methods and arrangements for the application of the 'storage' principle to television reception," *Teleg.- Fern.- und Funk-Tech.*, (Supplement), vol. 27, pp. 518–524; November, (1938).

[16] M. von Ardenne, "Storage methods in television reception," *Television*, vol. 12, pp. 67–72; February, (1939).

[17] A. Boni, "Calculation by successive approximations of the electrostatic field of a cylindrical system," *Radio e Televisione*, vol. 3, pp. 335–346; May, (1939).

[18] Cutte, "The focusing of electrons possessing high velocities and the general properties of centered systems in relativistic mechanics," *Rev. Gen. de l'Élec.*, vol. 45, pp. 675–677; May 20, (1939).

[19] M. von Ardenne, "On an electrostatic high-voltage lens of short focal length." *Naturwiss.*, vol. 27, pp. 114–115; September 8, (1939).

[20] Gundert, "The aperture error of electrostatic tube lenses," *Zeit. für Phys.*, vol. 112, pp. 689–690; June 1, (1939).

[21] Hillier, "The effect of chromatic error on electron microscope images," *Canadian Jour. Res.*, vol. 17, pp. 64–69; April, (1939).

[22] M. von Ardenne, "Remarks on the magnitude of the chromatic error in the electron microscope," *Zeit. für Phys.*, vol. 113, pp. 257–259; July 4, (1939).

[23] Von Borries and Ruska, "Experiments, calculations and results of the problem of the resolving power of the super microscope," *Zeit. für Tech. Phys.*, vol. 20, pp. 225–235; no. 8, (1939).

[24] M. von Ardenne, "Questions of intensity and resolving power of the electron microscope," *Zeit. für Phys.*, vol. 112, pp. 744–752; June 1, (1939).

[25] M. von Ardenne, "The electron raster microscope: Theoretical foundations," *Zeit. für Phys.*, vol. 109, pp. 553–572; July 11, (1938).

[26] Boersch, "The shadow microscope, a new electron supermicroscope," *Naturwiss.*, vol. 27, p. 418; June 9, (1939).

[27] M. von Ardenne, "Efficiency of the electron shadow microscope," *Naturwiss.*, vol. 27, pp. 485–496; July 14, (1939).

Work on oscillograph tubes continued. Tube development included the use of multiphase fields[28] for ultra-high-frequency waves and the design of multibeam tubes.[29] Beam-deflection theory relating to the deflecting-plate region has been refined to include effects of stray fields and their expression in terms of an equivalent uniform deflecting field.[30] Calculations of the optimum shaping of the deflecting plates for highest possible sensitivity were contributed.[31] An investigation was made of the cutoff phenomenon with electrostatic-deflection tubes as applied to frequencies at which the transit time is significant.[32]

Luminescent materials of improved properties were developed. A useful comprehensive survey of the state of the art has been published.[33]

Ultra-High-Frequency Tubes

The past year witnessed the publication of a number of papers on some new types of ultra-high-frequency electronic devices which are characterized by the use of electron beams and by unconventional input and output circuits.

Several of the reported developments of electronic devices, whose operation depends essentially on impressing a velocity variation on an electron stream, are closely related to some earlier work,[34] which appeared to receive scant recognition at the time of its publication.

Of such devices those variously referred to as "Klystrons" or as "Velocity-Modulation" tubes, or as using "Phase Focusing" form one class. In this class as a result of velocity variation, faster electrons tend to overtake slower electrons which preceded them, and the electrons subsequently become grouped when the stream is projected through a field-free region. After grouping has occurred, the stream is sent through an output region and may finally be collected at a relatively low velocity.

Whereas the earlier work was restricted, in that the input and output regions were interconnected, the more recent devices are often constructed so as to isolate the input and output portions of the structures. One device[35] described during the year employs input and output circuits in the form of electrically resonant cavities. More exact formulas for the resonant frequencies of such circuits have been developed and the coupling problems have been considered.[36–41]

Another device[42] employs electrodes in the form of cylinders whose lengths correspond to an electron transit time of an odd number of half periods at the operating frequency. Each of these electrodes doubles the number of points at which the circuit interacts with the electron stream. This is said to increase the over-all transadmittance of the device by a factor of approximately four.

A second general class of devices obtain electron grouping from velocity variations by the use of deflecting or reflecting fields to separate fast- and slow-moving electrons.[42]

While no detailed experimental results have been published, satisfactory operation of an amplifier of the velocity-variation type was described for frequencies as high as 6000 megacycles (5 centimeters), with an input conductance as low as 20 micromhos. Oscillators with outputs of 300 watts at about 1000 megacycles (30 centimeters) were also reported.[43]

A related device described during the year,[44] employed an electron beam and an electrically resonant cavity for its output circuit but depends upon the conventional grid for grouping of the electrons in the stream. An output of 110 watts with an efficiency of 35 per cent at 450 megacycles was reported, the required driving power being 10 watts. In a 500-megacycle tube with an output of 10 watts, the use of an improved focusing scheme has been disclosed and the operation of the device as a wide-band amplifier described.[45]

The general theory of electron grouping received considerable attention.[46–53] The analyses have in general taken two forms: one[42,46,47,52,53] in which the mutual

[28] H. E. Hollmann, "The deflection of cathode rays in multiphase fields," *Elek. Nach. Tech.*, vol. 15, pp. 336–341; November, (1938).

[29] A. Bigalke, "Four-beam electron tube of high writing velocity," *Arch. für Elektrotech.*, vol. 33, pp. 108–110; February 15, (1939).

[30] A. Thoma, "New investigations on cathode-ray oscillographs," *Funktech. Monatshefte*, no. 10, pp. 313–316; October, (1938); no. 11, pp. 329–331; November, (1938).

[31] Flechsig, "Electrostatic deflection in cathode-ray tubes with nonparallel deflecting plates," *Elek. Tech. Zeit.*, vol. 60, p. 798, July, (1939). (Summary only.)

[32] Hollmann, "Ultradynamic overcontrol of cathode-ray tubes," *Hochfrequenz. und Elektroakustik*, vol. 52, pp. 125–129; October, (1938).

[33] H. W. Levereng and F. Seitz, "Luminescent materials," *Jour. App. Phys.*, vol. 10, pp. 479–493; July, (1939).

[34] Arsenjewa-Heil and Heil, "A new method of producing short undamped waves of great intensity," *Zeit. für Phys.*, vol. 95, pp. 752–762; July 12, (1935).

[35] R. H. Varian and S. F. Varian, "A high-frequency oscillator and amplifier," *Jour. App. Phys.*, vol. 10, pp. 321–327; May, (1939).

[36] W. W. Hansen, "On the resonant frequency of closed concentric lines," *Jour. App. Phys.*, vol. 10, pp. 38–45; January, (1939).

[37] W. W. Hansen and R. D. Richtmyer, "On resonators suitable for Klystron oscillators," *Jour. App. Phys.*, vol. 10, pp. 189–199; March, (1939).

[38] F. Borgnis, "Electromagnetic natural vibrations of dielectric spaces," *Ann. der Phys.*, vol. 35, pp. 359–384; June 11, (1939).

[39] R. D. Richtmyer, "Dielectric resonators," *Jour. App. Phys.*, vol. 10, pp. 391–398; June, (1939).

[40] M. Jouguet, "On the natural electromagnetic oscillations of a cavity," *Compt. Rend.*, vol. 209, pp. 203–204; July 24, (1939).

[41] A. G. Clavier, "Theoretical relationships of dielectric guides," *Elec. Comm.*, vol. 17, pp. 276–290; January, (1939).

[42] W. C. Hahn and G. F. Metcalf, "Velocity-modulated tubes," Proc. I.R.E., vol. 27, pp. 106–116; February, (1939).

[43] "Cathode-ray amplifier tubes," *Electronics*, vol. 12, pp. 9–11; April, (1939).

[44] A. V. Haeff, "Ultra-high-frequency power amplifier of novel design," *Electronics*, vol. 12, pp. 30–32; February, (1939).

[45] A. V. Haeff and L. S. Nergaard, "A wide-band inductive-output amplifier," Proc. I.R.E., vol. 27, p. 610; September, (1939) (Abstract only.) (See this issue.)

[46] L. Mayer, "Experimental demonstration of phase focusing," *Zeit. für Tech. Phys.*, vol. 20, pp. 38–42; no 2 (1939).

[47] W. C. Hahn, "Wave energy and transconductance of velocity-modulated electron beams," *Gen. Elec. Rev.*, vol. 42, pp. 497–502; November, (1939).

[48] Simon Ramo, "The electronic-wave theory of velocity-modulation tubes," Proc. I.R.E., vol., 27, pp. 757–763; December, (1939).

repulsion effects between electrons are disregarded or at best are included only as a second-order correction, but which is applicable to large and small signals; and a second[50–52] in which space-charge forces are considered but in such a way as to limit the analysis to small signals. The large-signal theory indicates that a theoretical output efficiency of 58 per cent is possible.[52]

The problems associated with the formation and use of the electron beams required by the above devices received independent study.[54,55] Other theoretical advances included some progress in evaluating the high-frequency effects of double-valued electron velocities.[56]

The successful operation of a diode oscillator at 3000 megacycles (10 centimeters) was reported.[57]

Of the more conventional types of vacuum tubes[58,59] a 20-kilowatt tetrode amplifier suitable for use at frequencies up to 120 megacycles (2.5 meters) was described.[58] In order to minimize coupling between the input and output circuits the tube is of a special double-ended construction. A squirrel-cage screen is supported at both ends by radial flanges which can be connected to external shields so as to enclose the anode and the output circuit completely.

The flood of papers on tubes of the magnetron types which has been evident for several years continued. A magnetron has been described[60] which delivers 20 watts at 3750 megacycles (8 centimeters) with an efficiency of 20 per cent. Workers in Japan[61] reported outputs of 10 to 80 watts in the frequency range from 1765 to 3000 megacycles (17 to 10 centimeters) and efficiencies up to 88 per cent.

Receiving Tubes

The year continued the trend of recent years in refining methods of analysis and measurement and in furthering an understanding of basic phenomena.

Contributions to knowledge of the behavior of metals, both clean and coated, in relation to electron emission included (1) a useful up-to-date survey[62] of physical properties of oxide-coated cathodes and papers on the theories concerning their behavior;[63,64] (2) an analysis of the decay with time of temperature-limited thermionic emission from oxide-coated cathodes, with discussion as to whether it is a volume or a surface effect;[65] (3) experimental and theoretical studies of the relation between secondary electron emission and the energies of primary electrons;[66] and (4) accumulation of further data and greater perfection of the physical picture of electron behavior while within and escaping from metals, in relation to electronic energy levels and surface effects such as work functions, contact differences of potential, and surface potential structure.[67–72]

A number of workers continued investigations of noise phenomena. Flicker effect for the frequency range 40 to 20,000 cycles was discussed;[73] it appears that the mean-square noise current varies inversely with frequency rather than inversely with the square of the frequency as previously reported. Present knowledge of the tube noise was reviewed and general agreement between American, English, and German workers reported.[74,75]

Tube noise in frequency converters was found to be the average noise over an oscillator cycle.[76] The results were confirmed and applied to several types of frequency-converters for television use.[77]

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[49] G. Jobst, "Influence and control of the variable density of electron currents in tubes and the use of this phenomenon for generating short-wave oscillations by the impulse method," *Telefunken Hausmitteilungen*, vol. 20, pp. 84–96; July, (1939).

[50] W. C. Hahn, "Small signal theory of velocity-modulated electron beams," *Gen. Elec. Rev.*, vol. 42, pp. 258–270; June, (1939).

[51] Simon Ramo, "Space charge and field waves in an electron beam," *Phys. Rev.*, vol. 56, pp. 276–283; August 1, (1939).

[52] D. L. Webster, "Cathode-ray bunching," *Jour. App. Phys.*, vol. 10, pp. 501–508; July, (1939).

[53] D. L. Webster, "Theory of Klystron oscillators," *Jour. App. Phys.*, vol. 10, pp. 864–872; December, (1939).

[54] A. V. Haeff, "Space-charge effects in electron beams," Proc. I.R.E., vol. 27, pp. 586–602; September, (1939).

[55] J. R. Pierce, "Limiting current densities in electron beams," *Jour. App. Phys.*, vol. 10, pp. 715–724; October, (1939).

[56] W. Kleinsteuber, "The inference of space charge in planar braking-field tubes," *Hochfrequenz. und Elektroakustik*, vol. 53, pp. 199–213; June, (1939).

[57] F. B. Llewellyn and A. E. Bowen, "Production of ultra-high-frequency oscillations by means of diodes," *Bell. Sys. Tech. Jour.*, vol. 18, pp. 280–291; April, (1939).

[58] A. V. Haeff, L. S. Nergaard, W. G. Wagener, P. D. Zottu, R. B. Ayer, and H. E. Gihring, "Development of a 20-kilowatt ultra-high-frequency tetrode," Proc. I.R.E., vol. 27, pp. 610–611; September, (1939). (Summary only.)

[59] A. V. Haeff, "Effect of electron transit time on efficiency of a power amplifier," *RCA Rev.*, vol. 4, pp. 114–122; July, (1939).

[60] E. G. Linder, "The anode-tank-circuit magnetron," Proc. I.R.E., vol. 27, pp. 732–738; November, (1939).

[61] S. Uda, M. Isida, and S. Shoji, "High-efficiency sentron," *Electrotech. Jour.* (Tokyo), vol. 2, p. 291; December, (1938).

[62] J. P. Blewett, "The properties of oxide-coated cathodes," *Jour. App. Phys.*, vol. 10, pp. 668–670; October, and pp. 831–848; December, (1939).

[63] C. H. Prescott, Jr., and James Morrison, "The oxide-coated filament: The relation between thermionic emission and the content of free alkaline-earth metals," *Jour. Amer. Chem. Soc.*, vol. 60, pp. 3047–3053; December, (1938).

[64] C. H. Prescott, Jr., and James Morrison, "The true-temperature scale of an oxide-coated filament," *Rev. Sci. Inst.*, vol. 10, pp. 36–38; January, (1939).

[65] J. P. Blewett, "Time changes in emission from oxide-coated cathodes," *Phys. Rev.*, vol. 55, pp. 713–717; April 15, (1939).

[66] D. E. Wooldridge, "Theory of secondary emission," *Phys. Rev.*, vol. 56, pp. 562–578; September 15, (1939).

[67] R. L. E. Seifert and T. E. Phipps, "Evidence of a periodic deviation from the Schottky line, I," *Phys. Rev.*, vol. 56, pp. 652–663; October 1, (1939).

[68] D. Turnbull and T. E. Phipps, "Evidence of a periodic deviation from the Schottky line, II," *Phys. Rev.*, vol. 56, pp. 663–666; October 1, (1939).

[69] H. M. Mott-Smith, "Periodic deviation from the Schottky line," *Phys. Rev.*, vol. 56, pp. 668–669; October 1, (1939).

[70] W. Shockley, "On the surface states associated with a periodic potential," *Phys. Rev.*, vol. 56, pp. 317–323; August 15, (1939).

[71] E. V. Condon, "Notes on the external photoelectric effect of semiconductors," *Phys. Rev.*, vol. 54, p. 1089; December 15, (1938).

[72] P. Anderson, "Contact difference of potential between barium and magnesium," *Phys. Rev.*, vol. 54, p. 753; November 1, (1938).

[73] W. Graffunder, "Valve noise at low frequency," *Telefunken-Röhre*, no. 15, pp. 41–63; April, (1939).

[74] F. B. Llewellyn, "Report on noise in vacuum tubes," *U.R.S.I. Proc. of 1938 General Assembly, Venice and Rome*, vol. 5, pp. 8–12.

[75] E. B. Moullin, "Report on the present state of knowledge concerning fluctuation voltages in electrical networks and thermionic tubes," *U.R.S.I. Proc. of 1938 General Assembly, Venice and Rome*, vol. 5, pp. 12–17.

[76] E. Lukacs, F. Preisach, and Z. Szepesi, "Noise in frequency changer valves (Letter)," *Wireless Eng.*, vol. 15, p. 611; November, (1938).

[77] E. W. Herold, "Superheterodyne converter system considerations in television receivers," *RCA Rev.*, vol. 4, pp. 324–327; January, (1940).

Experiments indicate that for normal-incident primary electrons the decrease of secondary emission with increased atomic volume of the target results from the absorption of secondary electrons. For slow (10-volt) primary electrons, the more positive electropositive metals produce the greater secondary emission.[78]

The use of a conventional receiving tube as a negative-transconductance oscillator was described.[79] Theory and supporting measurements of input grid admittance as affected by electron path were reported for pentodes, heptodes, and octodes.[80]

Measurements of vacuum-tube properties were discussed in two papers covering (1) output-stage distortion[81] and (2) a precision method for measuring mutual conductance.[82]

Consideration was given to more-accurate calculation of the constants and space current of triodes with close spacings between the grid and the cathode. Approximate corrections for the effect of initial velocity of emission for the cathode are included.[83]

The use of spectrographic methods for the analysis of the chemical constitution of metals and of various gases and vapors was greatly extended during the past year. Such methods are now of increasing importance in comparative metallurgical analysis and in production control.[84] Spectrographic methods for the measurement of gas temperatures were also improved.

There appeared two papers on design characteristics, one on tetrode and pentode output tubes[85] and the other on the input conductance of radio-frequency tubes.[86]

The trend, noted in previous years, toward an increase in the number of tube types continued. This increase was produced, in part, by the demand for high-voltage-heater tubes for use in alternating-current—direct-current receivers. Other factors, such as reduction in envelope size, new basing arrangements, and new constructions also contributed. A number of new tubes designed for heater operation at 150 milliamperes and voltages ranging from 12 to 70 volts were introduced to eliminate the need for line-resistor cords or ballast tubes in alternating-current—direct-current receivers. Several tubes having 117-volt heaters were introduced to simplify the design of dual-purpose portable sets suitable for operation from a power line or a self-contained dry-battery supply. For small dry-battery sets a line of miniature tubes was introduced featuring conventional electrode structures in small envelopes and improved performance with 45-volt batteries. Their short over-all length, two inches, is made possible by "button-base" construction.[87]

A current movement to reduce the number of receiving-tube types began late in the year. It is further described in the report on radio receivers.[88]

Transmitting Tubes

The most-important advances in the field of large high-vacuum tubes during the year were in development of tubes suitable for very high frequencies. Many of these tubes are described in the section on ultra-high-frequency tubes although in the somewhat lower frequency range, advances also were made.[58,89,90,91] Particular mention may be made of a 20-kilowatt ultra-high-frequency tetrode.[58] The British[90] reported a sealed-off tube having a plate dissipation of 150 kilowatts, which delivered a peak power of 200 kilowatts at 13 meters.

There is noted a growing tendency toward air-cooling of large tubes.[89,92,93] Other advances were concerned largely with mechanical details.[94] A comprehensive survey of the construction, testing, and operation of large high-vacuum tubes, not included in the previous report, appeared in 1938.[95] The development

[78] H. Bruining and J. H. DeBoer, "Secondary electron emission," (in 5 parts) *Physica:* "Part I. Secondary emission of metals," vol. 5, p. 17; January, (1938). "Part II. Absorption of secondary electrons," vol. 5, p. 901; November, (1938). "Part III. Secondary electron emission caused by bombardment with slow primary electrons," vol. 5, p. 913; November, (1938). "Part IV. Compounds with a high capacity for secondary electron emission," vol. 6, p. 823; August, (1939). "Part V. The mechanism of secondary electron emission," vol. 6, p. 834; August, (1939).

[79] Cledo Brunetti, "The transitron oscillator," Proc. I.R.E., vol., 27, pp. 88–94; February, (1939).

[80] M. J. O. Strutt and A. van der Ziel, "Some dynamic measurements of electronic motion in multigrid valves," Proc. I.R.E., vol. 27, pp. 218–225; March, (1939).

[81] A. J. H. van der Ven, "Output-stage distortion: Some measurements on different types of output valves," *Wireless Eng.*, vol. 16, pp. 383–390; August; pp. 444–452; September, (1939).

[82] N. F. Astbury, "A precision method for the measurement of the mutual conductance of thermionic valves," *Jour. Sci. Inst.*, vol. 16, pp. 269–272; August, (1939).

[83] J. H. Fremlin, "Calculation of triode constants," *Elec. Comm.*, vol. 18, pp. 33–49; July, (1939); also *Phil. Mag.*, vol. 27, pp. 709–741; June, (1939).

[84] Symposium on spectroscopy, *Jour. App. Phys.*, vol. 10, November, (1939). W. F. Meggers, "Spectroscopic apparatus," pp. 734–740; R. A. Sawyer, "Qualitative and quantitative chemical analysis by line emission spectra," pp. 741–750; W. R. Brode, "Absorption spectra as applied to molecular identification and analysis," pp. 751–759; G. R. Harrison, "Compilations of spectroscopic data," pp. 760–767; H. M. Randall, "Infra-red spectra—observation and uses," pp. 768–779; and G. H. Dieke, "Molecular emission spectra," pp. 780–799.

[85] J. L. H. Jonker, "Pentode and tetrode output valves," *Wireless Eng.*, vol. 16, pp. 274–286; June; pp. 344–349; July, (1939).

[86] George Grammer, "Input resistance of r. f. receiving tubes: Effect on circuit gain and selectivity at high frequencies," *QST*, vol. 23, pp. 41–43, 90; May, (1939).

[87] K. G. Pucklin, "Miniature battery tubes," *Electronics*, vol. 12, pp. 27–28; November, (1939).

[88] "Radio progress during 1939—Part V—Radio receivers," Proc. I.R.E., this issue, page 119.

[89] Tj. Douma and P. Zijlstra, "Recording the characteristics of transmitting valves," *Philips Tech. Rev.*, vol. 4, pp. 56–60; February, (1939).

[90] E. Green and L. T. Moody, "100-kilowatt short-wave broadcasting transmitter type SWB-14 and 18," *Marconi Rev.*, no. 74, pp. 1–23; July–September, (1939).

[91] "New multi-purpose 357A operates at full ratings up to 100 megacycles," *Pick-ups*, pp. 16–34, July, (1939).

[92] M. Van der Beck, "Air-cooled transmitting valves," *Philips Tech. Rev.*, vol. 4, pp. 121–128; May, (1939).

[93] P. G. Cath, "A new principle of construction for radio valves," *Philips Tech. Rev.*, vol. 4, pp. 162–166; June, (1939).

[94] "200 kilowatt valves with replaceable filaments," *Gen. Elec. Rev.*, vol. 32, p. 369; August, (1939).

[95] J. Bell, J. W. Davies, and B. S. Gossling, "High power valves: Construction, testing, operation," *Jour. I.E.E.* (London), vol. 83, pp. 176–198; August, (1938); *Proc. Wireless Section*, vol. 13, p. 177; September, (1938).

of high-power tubes in the United States was curtailed by the present regulatory limitation on the power of broadcast stations.

Gas Tubes

Continued progress was made in the application of cold-cathode tubes[96] and magnetically controlled thyratrons.[97,98]

A new type of oxide-coated cathode for use in gas tubes was described.[99] This cathode consists of a central porous tubular filament filled with activating material and surrounded by vanes whose active coating surface is continuously replenished during life by evaporation from the central reservoir. Such cathodes appear to offer the possibility of extraordinarily long life.

Photoelectric Devices

Compared with previous years, there was a marked increase in the manufacture and use of photoelectric devices, but outstanding developments in new devices and tubes have not been apparent. A new tube employing rubidium[100] is now available, and improvements in design and construction were incorporated in many existing types. Removal of other sources of supply stimulated the manufacture in the United States of barrier-layer photocells. It is reported that cells with characteristics superior to imported units are now available from domestic production. A device for the rapid checking of the spectral sensitivity of phototubes and television pickup tubes was described,[101] and results indicate that it should be useful in production tests for uniformity.

There was a continued and widened use of photoelectric devices in varied applications. One novel application[102,103] at the New York World's Fair was in an exhibit at which the visitor rode along a 0.3-mile diorama representing "the world of tomorrow." A film-recorded description of the exhibit was picked up by a battery of 150 phototubes, each feeding an amplifier channel in such phase that the visitor heard from his own loud speaker a description of the scene immediately before him.

Substantiation of the work on thallium-sulphide surfaces,[104] mentioned last year, was reported. Several papers appeared[105,106,107] on the cause of time-lag phenomena in gas-filled phototubes. These indicate that the time lag can be traced to (1) transit time for the passage of positive ions in the discharge to the cathode and (2) transit time of metastable atoms also formed in the discharge.

Work on electron multipliers continued[108] although published reports on the subject are limited.

A number of developments reported during 1938 had their first formal publication in 1939.[109–114]

This report was prepared by the 1939 Technical Committee on Electronics of the Institute of Radio Engineers, the personnel of which follows:

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96 S. B. Ingram, "Cold-cathode gas-filled tubes as circuit elements," *Elec. Eng.*, vol. 58, pp. 342–346; July, (1939).

97 W. P. Overbeck, "The Permatron—A magnetically controlled industrial tube," *Elec. Eng.*, vol. 58, pp. 224–228; May, (1939).

98 W. P. Overbeck, "The Permatron and its application in industry," *Electronics*, vol. 12, pp. 25–28; April, (1939).

99 A. W. Hull, "The dispenser cathode—A new type of thermionic cathode for gaseous discharge tubes," *Phys. Rev.*, vol. 56, pp. 86–93; July 1, (1939).

100 A. M. Glover, "Spectral response of phototubes to new illuminants," *Electronics*, vol. 21, p. 20; December, (1939). (Abstract only.)

101 T. B. Perkins, "Automatic spectral-sensitivity curve tracer," *Jour. Opt. Soc. Amer.*, vol. 29, pp. 226–234; June, (1939).

102 James Dunlop and W. T. White, "An armchair spectator conveyer-guide," *Elec. Eng.*, vol. 58, pp. 509–514; December, (1939).

103 S. T. Stanton, F. R. Marion, D. V. Waters, "Polyrhetor," *Jour. Soc. Mot. Pic. Eng.*, vol. 33, pp. 485–501; November, (1939).

104 F. C. Nix and A. W. Treptow, "Thallous sulphide photo-e.m.f. cell," *Jour. Opt. Soc. Amer.*, vol. 29, pp. 457–462; November, (1939).

105 A. A. Kruithof, "Time-lag phenomena in gas-filled photoelectric cells," *Philips Tech. Rev.*, vol. 4, pp. 48–55; February, (1939).

106 W. S. Huxford, "Townsend ionisation coefficients in Cs-Ag-O phototubes filled with argon," *Phys. Rev.*, vol. 55, pp. 754–762; April 15, (1939).

107 R. W. Engstrom, "Time-lag analysis of Townsend discharge with activated caesium electrodes," *Phys. Rev.*, vol. 57, p. 73; January 1, (1940).

108 J. S. Allen, "Detection of single positive ions, electrons, and photons by a secondary electron multiplier," *Phys. Rev.*, vol. 55, pp. 966–971; May 15, (1939).

109 R. B. Janes and W. H. Hickok, "Recent improvements in the design and characteristics of the iconoscope," Proc. I.R.E., vol. 27, pp. 535–540; September, (1939). (See reference 1 in 1938 report.)

110 Harley Iams, G. A. Morton, and V. K. Zworykin, "The image iconoscope," Proc. I.R.E., vol. 27, pp. 541–547; September, (1939). (See reference 2 in 1938 report.)

111 C. Larson and B. C. Gardner, "The image dissector," *Electronics*, vol. 12, pp. 24–27, 50; October, (1939). (See reference 4 in 1938 report.)

112 V. K. Zworykin and J. A. Rajchman, "The electrostatic electron multiplier," Proc. I.R.E., vol. 27, pp. 558–566; September, (1939). (See references 13 and 68 in 1938 report.)

113 R. R. Law, "Contrast in kinescopes," Proc. I.R.E., vol. 27, pp. 511–524; August, (1939). (See reference 17 in 1938 report.)

114 A. P. Kauzmann, "New amplifier receiving tubes," *RCA Rev.*, vol. 3, pp. 271–289; January, (1939). (See references 25 and 62 in 1938 report.)

of condensers.[43,44] Other types of disturbance were investigated and methods of reduction found.[45–48] The cause of scattering of results in the measurement of disturbance voltages by the CISPR Technique was studied[49] and a possible remedy suggested. Legislation was enacted in several countries in an effort to reduce the amount of man-made radio noise by control at the source.[42–50] In the large metropolitan areas this is the major source of disturbance.

A co-operative program by a number of investigators[51,52] interested in aircraft radio reception resulted in means of reducing the disturbance called precipitation static. The results of this work were found to be applicable to ground stations.

High Frequencies (1500 to 30,000 Kilocycles)

Radio wave propagation in this range of frequencies is almost entirely by way of the ionosphere. There was substantial progress during the year in the use of ionospheric data to calculate or predict radio transmission conditions. This included methods of calculating[53–55] maximum usable frequencies for any transmission distance from critical frequencies and virtual heights of the ionospheric layers, and working out[56] from such data the choice of optimum frequencies, times at which to shift frequency, etc.

The year saw the inauguration of a regular service of prediction[27,57] of maximum usable frequencies by the National Bureau of Standards; this was given in the monthly ionosphere report in the Proceedings of the Institute of Radio Engineers for the month following the month of publication. The predictions are in the form of graphs for various distances, giving maximum usable frequencies as a function of time of day; they are based on the Bureau's current observations, on its data on the trends[58] of critical frequencies and virtual heights in the 11-year solar cycle, data on seasonal and diurnal variations accumulated over a number of years, and knowledge of solar variations.[59,60] The maximum usable, and also optimum, frequencies in 1939 averaged about 8 per cent lower than in 1938, and about 11 per cent lower than in 1937. By about 1944 they are expected to be about half those of 1937 (last sunspot maximum) and equal to those of 1933 (last sunspot minimum).

Extension of the value of ionospheric data for practical radio purposes depends upon[61] the availability of such data from a number of places on the earth's surface. Ionospheric data taken regularly for all the 24 hours of the day are especially useful. Such data for Washington, D. C., (latitude 39 degrees north) published throughout several past years, continued to appear monthly[27] and quarterly.[62] Such data became available[63,64] for two additional places, Peru (Hunacayo, 12 degrees south), and Australia (Watheroo, 30 degrees south), published quarterly. Valuable but much less complete data were published for three other places.[65,66,67] It was shown[68] that ionospheric characteristics differ somewhat in different places, the differences being small when the places are not over a few hundred miles apart.

It was proved[69] that under some conditions radio waves over long distances deviate considerably from the great-circle plane. In general, on an all-daylight path between England and New York such deviations

[43] S. Lemoine, "Using condensers for eliminating interference from electrical tramways," *Wireless Eng.*, vol. 16, p. 3; January, (1939).

[44] L. A. Fomenko, "The suppression of interference from industrial apparatus by blocking condensers," *Izvestiya Elektroprom. Slab. Toka*, pp. 17–28.

[45] K. Kegel, "General viewpoints of interference suppression," *A. E. G.-Mitteilungen*, pp. 380–383; August, (1939).

[46] "Low-cost cure for radio interference," *Sci. American*, vol. 160, p. 350; June, (1939).

[47] E. T. Glas, "Broadcast interference caused by high-tension installations," *Elek. Tech. Zeit.*, vol. 59, pp. 1305–1306; December, (1938).

[48] "Service instructions for the detection and elimination of interference with radio reception. Instituto Sperimentale delle Communicazioni," *Bolletino del Centro Volpi di Elettrologia*, Year I, p. 73; December, (1938). (Summary only.)

[49] G. Goffin, "A cause of scattering in the measurement of radiophonic interfering voltages," *L'Onde Élec.*, vol. 18, (wrongly printed 19), pp. 57–69; February, (1939).

[50] E. Paolini, "The question of industrial parasites in broadcast reception," *Alta Frequenza*, vol. 8, pp. 377–389; June, (1939).

[51] H. M. Hucke, "Precipitation static interference on aircraft and at ground stations," Proc. I.R.E., vol. 27, pp. 301–316; May, (1939).

[52] Esau, Jansky, Kotowski, and Klumb, "Radio reception in aviation," *Zeit. V.D.I.*, vol. 83, p. 416; April, (1939). (Summaries only.)

[53] N. Smith, "The relation of radio sky-wave transmission to ionosphere measurements," Proc. I.R.E., vol. 27, pp. 332–347; May, (1939).

[54] M. V. Wilkes, "Theoretical ionization curves for the E region." *Proc. Phys. Soc.* (London), vol. 51, pp. 138–146; January, (1939).

[55] H. G. Booker and S. L. Seaton, "Relation between actual and virtual ionospheric height," *Phys. Rev.*, vol. 57, pp. 87–94; January 15, (1940).

[56] N. Smith, S. S. Kirby, and T. R. Gilliland, "Application of graphs of maximum usable frequency to communication problems," *Jour. Res. Nat. Bur. Stand.*, vol. 22, pp. 81–92; January, (1939).

[57] N. Smith and A. S. Taylor, "The prediction of ionosphere characteristics and maximum usable frequencies," Presented, I.R.E.–U.R.S.I. meeting, Washington, D. C., April 29, (1939).

[58] N. Smith, T. R. Gilliland, and S. S. Kirby, "Trends of characteristics of the ionosphere for half a sunspot cycle," *Jour. Res. Nat. Bur. Stand.*, vol. 21, pp. 835–845; December, (1938).

[59] W. M. Goodall, "The solar cycle and the F_2 region of the ionosphere," Proc. I.R.E., vol. 27, pp. 701–704; November, (1939).

[60] C. H. Anderson, "A representation of the sunspot cycle," *Bell Sys. Tech. Jour.*, vol. 18, pp. 292–299; April, (1939).

[61] J. H. Dellinger, "Report of Commission II, Radio Wave Propagation, International Scientific Radio Union," Proc. I.R.E., vol. 27, pp. 645–649; October, (1939).

[62] "Averages of critical frequencies and virtual heights of the ionosphere, observed by the National Bureau of Standards at Washington, D. C." Published quarterly in *Terr. Mag.*

[63] H. W. Wells and H. E. Stanton, "The ionosphere at Huancayo, Peru." Published quarterly in *Terr. Mag.*

[64] W. C. Parkinson and L. S. Prior, "The ionosphere at Watheroo, Western Australia." Published quarterly in *Terr. Mag.*

[65] I. Ranzi, "Ionospheric observations," *La Ricerca Sci.*, vol. 10, pp. 32–38; January-February (1939).

[66] L. Harang, "Annual variation of the critical frequencies of the ionized layers at Tromso during 1938," *Terr. Mag.*, vol. 44, pp. 15–16; March, (1939).

[67] W. M. Goodall, "Midday F_2-region critical frequencies for Deal, New Jersey," *Terr. Mag.*, vol. 44, p. 212; June, (1939).

[68] J. P. Schafer and W. M. Goodall, "Simultaneous ionosphere observations at Washington, D. C. and Deal, N. J.," *Terr. Mag.*, vol. 44, pp. 205–208; June, (1939).

[69] C. B. Feldman, "Deviations of short radio waves from the London–New York great-circle path," Proc. I.R.E., vol. 27, pp. 635–645; October, (1939).

did not occur, and neither ionospheric storms nor sudden ionospheric disturbances affected the mode of propagation. On the other hand, on dark or partially illuminated paths the great circle no longer provides the sole transmission path. The extent to which other paths are involved varies greatly. Propagation during ionospheric storms of moderate intensity usually involves paths deviated to the south of the great circle; at other times propagation may be either to the north or south. The closely related subject of scattered reflections was the subject of considerable investigation.[70–73] Some observations[74] during magnetic storms and annual displays showed that the sporadic E layer has a sharper lower boundary than the normal E layer.

Further data were accumulated on the phenomena characterizing ionospheric storms.[27,28,75] It was established that the effects of this particular type of ionospheric disturbance are less at low than at high latitudes. Effects at broadcast frequencies are reviewed under "Medium Frequencies," above.

A study was made of the vertical angle of arrival of atmospherics.[76] The angle sometimes approaches 90 degrees, becoming lower as the disturbance decreases. An extensive study was made of the spectrum distribution[77] of atmospherics at high frequencies.

Ultra-High Frequencies (Over 30,000 Kilocycles)

Propagation at these frequencies takes place by three means: (a) by ground waves, (b) by tropospheric waves, and (c) at frequencies not very far above 30,000 kilocycles, by ionospheric waves. Progress in regard to (a) ground waves is reviewed in the "General" section above.

Progress in tropospheric wave propagation centered on two principal phenomena. One was the refraction of radio waves around the curved surface of the earth by gradients and discontinuities with height of the dielectric constant of the air. Work[78] in this field confirmed the importance of these phenomena in the application of the ultra-high frequencies to communication services. It was found[79] that these effects may result in either increased or decreased distance ranges of transmission and that it depends particularly on the position (height) of the transmitting and receiving aerials, with respect to the refracting air layers, whether the received field intensity is under or over the normal value. Tropospheric radio transmission was found to have the possibility of applications in meteorology.[80–82]

The second phenomenon of interest in tropospheric wave propagation was the reception of echoes at vertical (or nearly vertical) incidence from heights within the troposphere, i.e., less than about 10 kilometers. It was found that the waves are not reflected from ionized strata but rather are reflected comparatively weakly (reflection coefficients not greater than 10^{-4}) from air-mass discontinuities in which water in its various states plays a dominant rôle.[82–85]

The occurrence of long-distance ionospheric propagation at frequencies up to about 45 megacycles was reported and studied.[11,86,87] This was sometimes not so much by reflection from regular layers of the ionosphere as sometimes by sporadic or scattered reflections.

The problem of interference with television reception was given an increased amount of study. A new noise meter, intended primarily for measuring such interference was developed under the auspices of a Radio Manufacturers Association Subcommittee on Television Interference.[88] In an attempt to promote some constructive action on the serious problem of interference to television and other radio services caused by electromedical equipment, a conference was held in New York in January at which representatives of the American Medical Association, the Federal Communications Commission, various radio societies, and the radio industry were present.[89] Negotiations

[70] L. Harang and W. Stoffregen, "Scattered reflections of radio waves from height of more than 1000 km.," *Nature*, vol. 142, p. 832; November 5, (1938).

[71] T. L. Eckersley, "Scattering of radio waves in the ionosphere," *Nature*, vol. 143, pp. 33–34; January 16, (1939).

[72] E. V. Appleton and R. Naismith, "Scattering of radio waves in polar regions," *Nature*, vol. 143, pp. 243–244; February 11, (1939).

[73] B. Beckmann, W. Menzel, and F. Vilbig, "Scattered reflections in the ionosphere," *Teleg.- Fern.- und Funk-Tech.*, vol. 28, pp. 130–135; April, (1939).

[74] L. Harang and W. Stoffregen, "The polarization condition of radio waves by reflection on layers which are formed by magnetic storms and northern lights," *Hochfrequenztech. und Elektroakustik*, vol. 53, pp. 181–187; June, (1939).

[75] L. V. Berkner, H. W. Wells, and S. L. Seaton, "Ionospheric effects associated with magnetic disturbances," *Terr. Mag.*, vol. 44, pp. 283–311; Spetember, (1939).

[76] M. Nakagami and K. Miya, "Incident angle of short waves and high-frequency noise (resembling 'grinders') during Dellinger effect," *Elec. Jour.* (Tokyo), vol. 3, p. 216; September, (1939).

[77] O. Morgenroth, "Atmospheric disturbances," *Funktech. Monatshefte*, no. 3, pp. 70–74; March, (1939).

[78] K. G. MacLean and G. S. Wickizer, "Notes on the random fading of 50-megacycle signals over nonoptical paths," Proc. I.R.E., vol. 27, pp. 501–506; August, (1939).

[79] W. Scholz and L. Egersdorfer, "On the influence of the troposphere on ultra-short-wave propagation," *Teleg.- Fern.- und Funk-Tech.*, vol. 28, pp. 77–83; March, (1939).

[80] A. W. Friend, *Bull. Amer. Meteor. Soc.*, vol. 20, pp. 202–205; May, (1939).

[81] A. W. Friend, *Nature*, vol. 144, p. 31: July 1, (1939).

[82] A. W. Friend and R. C. Colwell, "The heights of the reflecting regions in the troposphere," Proc. I.R.E., vol. 27, pp. 626–634; October, (1939).

[83] J. H. Piddington, "The origin of radio-wave reflections in the troposphere," *Proc. Phys. Soc.* (London), vol. 51, pp. 126–137; January, (1939); vol. 51, pp. 547–548; May, (1939).

[84] O. H. Gish and H. G. Booker, "Nonexistence of continuous intense ionization in the troposphere and lower stratosphere," Proc. I.R.E., vol. 27, pp. 117–125; February, (1939).

[85] R. C. Colwell and A. W. Friend, "Tropospheric reflections of radio waves," *U.R.S.I. Proc. of 1938 General Assembly*, vol. 5, pp. 146–149; (1938).

[86] O. Burkard, "Limiting waves and the ionosphere: III," *Hochfrequenz. und Elektroakustik*, vol. 52, pp. 142–146; October, (1938).

[87] D. R. Goddard, "Transatlantic reception of London television signals," Proc. I.R.E., vol. 27, pp. 692–695; November, (1939).

[88] Jerry Minter, "Noise measurements in the television bands," *Electronics*, vol. 12, p. 21; December, (1939). (Abstract only.)

[89] "Summary of informal discussion on interference to radio reception caused by electro-medical equipment, New York, January 9, 1939." Federal Communications Commission, No. 32683, (1939).

were begun between representatives of the automotive industry and the Radio Manufacturers Association, looking toward alleviation of the problem of ignition interference.

Experiments have been carried on in order to determine the effectiveness of frequency modulation in respect to disturbance.[90–92] A considerable advantage in comparison with amplitude modulation was indicated if the peak radio noise voltage is somewhat less than the signal voltage.

Atmospherics at about 150 megacycles were investigated.[34] The technique of observations provided a visual indication of the disturbance which might be expected with television signals. It appears that atmospherics due to thunderstorms will be noticeable for ultra-high-frequency television transmission at times when storms are in progress near the point of reception.

[90] I. R. Weir, "Field tests of frequency and amplitude modulation with ultra-high-frequency waves," *Gen. Elec. Rev.*, vol. 42, pp. 188–191; May, and pp. 270–273; June, (1939). Abstract, Part I, *Electronics*, vol. 12, p. 70; June, (1939).

[91] "The first high-powered radio station without static," *Science*, vol. 89, p. 72; January 27, (1939).

[92] "Frequency modulation demonstrated," *Electronics*, vol. 12, pp. 14–17; March, (1939).

A new line of progress developed in connection with wave guides. The radiation (transmitting and receiving) properties of various types of terminating electromagnetic horns were analyzed[93,94] in detail and practical applications outlined. This work led to some improvements[95,96] in the theory of diffraction of electromagnetic waves.

This report was prepared by the 1939 Technical Committee on Wave Propagation of the Institute of Radio Engineers, the personnel of which follows:

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[93] W. L. Barrow and L. J. Chu, "Theory of the electromagnetic horn," Proc. I.R.E., vol. 27, pp. 51–64; January, (1939).

[94] G. C. Southworth and A. P. King, "Metal horns as directive receivers of ultra-short waves," Proc. I.R.E., vol. 27, pp. 95–102; February, (1939).

[95] J. A. Stratton and L. J. Chu, "Diffraction theory of electromagnetic waves," *Phys. Rev.*, vol. 56, pp. 99–107; July 1, (1939).

[96] S. Schelkunoff, "On diffraction and radiation of electromagnetic waves," *Phys. Rev.*, vol. 56, pp. 308–316; August 15, (1939).

PART IV—TRANSMITTERS AND ANTENNAS*

Transmitters: Marine—Centimeter Waves—Frequency and Phase Modulation—Regulation—Television—Point-to-Point—Instrument Navigation Equipment
Antennas: Television—Steerable Antenna—Horn Radiators

Transmitters

The year's developments in broadcast transmitters employing amplitude modulation were chiefly along the lines of refinements of earlier fundamental developments. One of such developments is the use of circuits of high power efficiency, whose application has been broadened and improved. For example, several manufacturers now offer air-cooled 5-kilowatt transmitters, the problems of cooling being considerably simplified by improved efficiency. A new 1-kilowatt transmitter appeared in which a high-efficiency circuit is employed in conjunction with grid-bias modulation. At this low power level the advantage lies more in lower tube cost resulting from reduced dissipation than in power saving. Manufacturers of power tubes are extending the use of air-cooling to tubes of higher power. By means of new designs made available late in the year, it became possible to build air-cooled transmitters up to 50 or more kilowatts. New applications of multiphase alternating current for filament lighting were made.

Stabilized feedback continued to be an important feature of transmitter design. Nearly all new transmitters made use of this principle to give high-fidelity performance and to permit less-expensive filtering equipment and alternating-current filament heating.

Modern styling continued to be a feature of broadcast transmitters and associated apparatus.

Refinements in speech-input equipment were evident in circuit design and in equipment arrangement and styling.

A much-needed step was taken in the standardization of the volume unit and its incorporation in a new standard volume indicator.[1]

Marine

In the marine field new radio transmitters were offered by several of the major communication organizations for both the intermediate-frequency and high-frequency bands. These new transmitters are characterized by crystal control. Previously the use of crystal control for ship transmitters was limited and was usually applied to radiotelephone equipment only.

Centimeter Waves

Important progress was made in devices to produce increased power and stability on centimeter waves.

* Decimal classification: R350×R320.

[1] H. A. Chinn, D. K. Gannett, and R. M. Morris, "A new standard volume indicator and reference level," Proc. I.R.E., vol. 28, pp. 1–16; January, (1940).

Common to all of the devices referred to is the use of cathode-ray beams and the use of inductive power generation, the function of electron collecting being assigned to a separate electrode. The cathode-ray beam is varied by some form of control electrode.

There are at least two types of variation used. In one of these[2] the number of electrons in the beam, that is, the electron density, is varied in much the same way as in the conventional triode, by means of a control grid. This variation, produced at the control grid, is maintained (per unit length) substantially constant to the point where power is collected.

In the second type of variation[3–8] called "velocity modulation," the electron velocity, not its density, is varied at the control grid, the requisite variations in density not developing until the electrons have drifted down the beam to the power-collecting point. Different names have been given in different laboratories to the latter type of device, notably "drift tubes" and "Klystrons."

These devices appear to possess certain advantages over conventional types, among which are increased power capability at wavelengths in the decimeter range, reduction of the input-admittance component caused by transit time (at least in the drift-tube type). It is naturally too early to assess their ultimate advatages or disadvantages in radio transmitters, but it can be said that they are already being used for that purpose. A power of 300 watts at 1000 megacycles has been reported with an efficiency of 30 to 40 per cent.[9]

Utilizing an anode-tank-circuit[10] magnetron, an output of 20 watts at 3750 megacycles and an efficiency of 22 per cent have been obtained.

Frequency and Phase Modulation

Considerable interest was shown in frequency and phase modulation[11–13] for services which utilize the ultra-high frequencies. Applications for broadcast licenses to make use of frequency modulation on an experimental basis were being filed with the Federal Communications Commission at a rate of about three a week at the end of the year. Equipment manufacturers offered transmitters for this type of service for operation in the 40,000-kilocycle band and at power outputs ranging from 100 to 50,000 watts. Several receiver manufacturers offered frequency-modulated-wave receivers for sale to the public at prices ranging between $60 and several hundred dollars. Several frequency-modulated-wave broadcast stations were in operation at the end of the year and were transmitting the regular programs carried by stations operating in the 500-to-1600-kilocycle band. One of them utilized 40,000 watts power.

It was demonstrated that frequency modulation occasions a large noise advantage over amplitude modulation provided that the field intensity at the receiving point is somewhat greater than the noise intensity. A large saving in transmitting-tube capacity is also occasioned by frequency modulation because the amplitude of the transmitted wave remains constant during modulation.

The Federal Communications Commission restricted frequency modulation to experimental use in broadcasting and assigned 13 frequencies exclusively for that service. On the basis of preliminary information, it appears that stations may be duplicated on each channel if a geographical separation of roughly 300 miles is maintained.[14] The relaying of programs successively though several frequency-modulated-wave stations was demonstrated.[15]

Regulation

The Federal Communications Commission made sweeping revisions in the "Rules and Standards of Good Engineering Practice" covering many of the radio services. Important changes were made in frequency-allocation requirements for minimum and maximum powers, permissible carrier-frequency tolerances, safety requirements, procedure, antenna requirements, etc. Most of the changes became effective during the year, but some will become effective in 1940 and 1941.

Television

The year 1939 marked the inauguration of the first regularly scheduled and permanent television service to the public in the Americas. Approximately 12 program hours per week were provided in the areas served. These programs consisted of motion pictures, dramatic, comedy, and variety productions, news, and sporting events direct from the scene of action. Trans-

[2] A. V. Haeff, "A new ultra-high-frequency amplifier of unique design," *Electronics*, vol. 12, pp. 30–32; February, (1939).
[3] W. C. Hahn and G. F. Metcalf, "Velocity-modulated tubes," Proc. I.R.E., vol. 27, pp. 106–116; February, (1939).
[4] W. W. Hansen and R. D. Richtmyer, "On resonators suitable for Klystron oscillators," *Jour. App. Phys.*, vol. 10, pp. 189–199; March, (1939).
[5] W. C. Hahn, "Small signal theory of velocity-modulated electron beams," *Gen. Elec. Rev.*, vol. 42, p. 258–270; June, (1939).
[6] Simon Ramo, "Space charge and field waves in an electron beam," *Phys. Rev.*, vol. 56, p. 276–283; August 1, (1939).
[7] W. C. Hahn, "Wave-energy and trans-conductance of velocity-modulated electron beams," *Gen. Elec. Rev.*, vol. 42, pp. 497–502; November 19, (1939).
[8] Simon Ramo, "The electronic-wave theory of velocity-modulation tubes," Proc. I.R.E., vol. 27, pp. 757–763; December, (1939).
[9] "Cathode-ray amplifier tubes," *Electronics*, vol. 12, p. 9; April, (1939).
[10] E. G. Linder, "The anode-tank-circuit magnetron," Proc. I.R.E., vol. 27, pp. 732–738; November, (1939).
[11] M. G. Crosby, "Communication by phase modulation," Proc. I.R.E., vol. 27, pp. 126–136; February, (1939).
[12] J. R. Carson, "Frequency modulation: Theory of the feedback receiving circuit," *Bell Sys. Tech. Jour.*, vol. 18, pp. 395–403; July, (1939).
[13] J. G. Chaffee, "The application of negative feedback to frequency-modulation systems," Proc. I.R.E., vol. 27, pp. 317–331; May, (1939); *Bell. Sys. Tech. Jour.*, vol. 18, pp. 404–437; July, (1939).
[14] I. R. Weir, "Field tests of frequency and amplitude modulation with ultra-high-frequency waves," *Gen. Elec. Rev.*, vol. 42, pp. 188–191 and 270–273; May and June, (1939). Abstract Part I, *Electronics*, pp. 12, 70; June, (1939).
[15] "F-M broadcasting on three relays proves successful," *Broadcasting*, vol. 17, p. 26; December 15, (1939).

mitters became available as standard equipment, and television receivers were sold to the public for the first time. Although the Federal Communications Commission has not authorized commercial operation, one class of station is permitted to accept payment sufficient to cover the costs of program production.

At one station a radio link between the studio and and transmitter site is used to relay the programs. Television programs have been successfully received from a New York City station and relayed over a station near Schenectady (129 miles).

Point-to-Point

Developments in commercial telephone-communication channels during the year included modification for twin-channel operation of the single-channel, single-sideband short-wave circuit between San Francisco and Honolulu and the addition of a second such circuit to the existing one between New York and London. Twin-channel operation denotes the operation of two channels, one in each sideband of the same carrier frequency. The single-channel single-sideband long-wave transmitter at Rocky Point, Long Island, has also been modified for twin-channel operation.[16]

The requirement of constant supervision of a trans-atlantic radiotelephone channel by a technical operator was reduced to occasional supervision only by the use of a semiautomatic control terminal which incorporates, for control of transmitting volume,[17] a vogad (voice-operated gain-adjusting device) and for control of receiving volume a tola (tone-operated loss adjuster).

The development of measuring equipment for commercial use at ultra-high frequencies provided means for overcoming the widespread uncertainty as to ultra-high-frequency transmission conditions.

Instrument Navigation Equipment

An instrument landing system utilizing[18] 40-centimeter (750-megacycle) waves was demonstrated to Civil Aeronautics Authority officials at East Boston airport. Two metal-horn radiators were fed by separate transmitters, one modulated at 90 cycles and the other at 150 cycles and both operating on a frequency of approximately 750 megacycles. The horns, each of which produces a flat horizontal beam, are inclined, respectively, 5 and 10 degrees above the earth's surface. The beams overlap providing a gliding signal. This vertical guidance system was supplemented by a horizontal guidance system of conventional design. The 700-megacycle transmitters were designed for the Klystron tube which, in other tests utilizing less than 100 watts power, had shown the system described to be effective at a distance of 25 miles. A somewhat different system for instrument landing[19] has been accepted by the Civil Aeronautics Authority and will be placed in service in 1940 and 1941 at many of the country's major airports. This system was demonstrated at the Indianapolis Airport. It consists of a glide-path beam and two marker beams. The outer marker transmitter produces a modulated vertically directed local signal about two miles from the airport on the line of approach and indicates to the pilot that he should start his glide. The second marker transmitter, modulated differently from the first indicates that the airplane has reached the area where contact may be made with the ground. A glide-path transmitter gives vertical guidance throughout the approach. The marker units operate on 75 megacycles with 5 watts, the outer unit modulated at 400 cycles keyed twice per second and the inner unit at 1300 cycles keyed at six pulses per second. The localizer transmitter operates on 109.9 megacycles with 300 watts.

Radio altimeter equipment[20] was offered for commercial use. It gives continuous and instantaneous readings of the distance between plane and terrain throughout an altitude range of from 50 to 5000 feet. The indication of altitude is independent of changes in air pressure, temperature inversions, humidity, cloud layers, and other variable factors of weather. It is not affected by static and requires no adjustment by the pilot. Absolute altitude above the terrain is indicated by sending a frequency-modulated wave to the ground and timing the interval required for it to reach the ground and return to the plane after it has been reflected from the ground. The direct and reflected signals are applied to a detector circuit in a radio receiver and their instantaneous difference in frequency is directly proportional to the height of the airplane above ground. The frequency difference is applied to a cycle-counting circuit including a meter with the scale calibrated in feet of altitude, and this meter is located on the airplane instrument panel in full view of the pilot.

Antennas

The year 1939 saw further increase in the use of directive antenna arrays for broadcast service. The broadcast frequencies are now so well occupied throughout the country that it is seldom possible to secure Federal Communications Commission approval for a new station without using a directive array. Such an array serves one or both of two purposes, namely, to reduce radiation in certain directions to protect other stations from interference and to concentrate radiation toward preferred service areas.

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

[17] S. B. Wright, S. Doba, and A. C. Dickieson, "A vogad for radiotelephone circuits," Proc. I.R.E., vol. 27, pp. 254–257; April, (1939).

[18] "40-cm. waves for aviation," *Electronics*, vol. 12, pp. 12–15; November, (1939).

[19] "Instrument landing systems," *Communications*, vol. 19, pp. 9, 25, 26, 29; November, (1939).

[20] Lloyd Espenschied and R. C. Newhouse, "A terrain clearance indicator," *Bell Sys. Tech. Jour.*, vol. 18, pp. 222–234; January, (1939).

In line with the more-intense interest being shown in antenna performance, a few investigators have undertaken to verify the performance of antennas above the horizontal plane by airplane surveys. A certain amount of work was also done on vertical patterns by means of scale models at ultra-high frequencies.

At ultra-high frequencies experimentation continued with a variety of directional-antenna forms. Such experimentation naturally yields results more readily than at broadcast frequencies because of the more-practical physical dimensions involved.

It was reported during the year[21] that progress with the multiple-unit steerable receiving antenna (musa), previously described[22] reached the stage of commercial application on radiotelephone circuits between New York and London.

Television

The requirement of nondirectional coverage in a horizontal plane for broadcast service resulted in the development of the turnstile antenna described in previous reports. The added requirement of wide frequency band width for television service was met during the current year. This development, although rapid, was made in gradual steps starting from the conventional dipole, going to a similar radiator but with large-diameter conductors, then to the "folded" dipole and combinations of them, and finally coming to the "double-cone" radiator as the last step in the simple-antenna series.

A television antenna successfully meeting the broadband requirement of the new standards was developed and installed atop the Empire State Building in New York City.[23,24] This structure is basically of the turnstile form, consisting of two horizontal half-wave resonators set at right angles and excited in quadrature. The noteworthy features are the careful proportioning of parts to the end that the coaxial transmission lines feeding the antenna are properly terminated at their characteristic impedance, without the use of additional circuits for the purpose located at the antenna and the extremely wide band of frequencies transmitted with negligible reflection. The four quarter-wave radiators are ellipsoidal in shape and with their collars are proportioned so that the square root of the inductance-capacitance quotient in effect has been made equal to the radiation resistance, and departs little from this condition over a band six times that assigned for a single television channel.

The sound antenna consists of 4 folded dipoles arranged in the form of bent segments in a horizontal plane around a central support and above the plane of the vision antenna. The canceling effect of the opposite segments as connected to the common transmission line feeding the segments in parallel results in the approximate equivalent of a loop antenna with almost complete freedom from coupling to the diametrically located radiators of the vision antenna. This feature is interesting because it permits the two antennas to operate without mutual interference in such close proximity.

Steerable Antenna

There has been an application in America and one in Europe of steerable directive transmitting antennas for international broadcasting. By the use of remotely controlled phasing units in the feed circuits to the several bays comprising a directive antenna, the direction of maximum transmission may be shifted to preselected areas. This use of controllable horizontal directivity makes possible flexibility and economies in the number of high-gain antennas required to provide optimum service.

Horn Radiators

It was shown that metal horns have many[25–27] advantages for transmission and reception of electromagnetic waves at wavelengths below 100 centimeters. Some of the advantages consist of unusual freedom from secondary lobes and stray radiation, simple construction, transmission of a very broad band width, ease and stability of operation, and high power gain. The power gain is roughly proportional to the area of aperture. Power gains of over 100 are obtained without difficulty and there is no reason to believe that this is an upper limit. Through the use of combinations of horns and variations in their configurations, a variety of specialized requirements may be met. An airplane instrument blind-landing system is one application.

This report was prepared by the 1939 Technical Committee on Transmitters and Antennas of the Institute of Radio Engineers, the personnel of which follows:

E. G. Ports, Chairman

Raymond Asserson	*W. E. Jackson*
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[21] F. A. Polkinghorn, "A single-sideband MUSA receiving system for commercial operation on transatlantic radiotelephone circuits," Proc. I.R.E., vol. 27, p. 614; September, (1939). (Abstract only.)

[22] 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).

[23] N. E. Lindenblad, "Television transmitting antenna for Empire State Building," *RCA Rev.*, vol. 3, pp. 387–408; April, (1939).

[24] P. S. Carter, "Simple television antennas," *RCA Rev.*, vol. 4, pp. 168–185; October, (1939).

[25] W. L. Barrow and L. J. Chu, "Theory of the electromagnetic horn," Proc. I.R.E., vol. 27, pp. 51–64; January, (1939).

[26] G. C. Southworth and A. P. King, "Metal horns as directive receivers of ultra-short waves," Proc. I.R.E. vol. 27, pp. 95–102; February, (1939).

[27] W. L. Barrow and F. D. Lewis, "The sectoral electromagnetic horn," Proc. I.R.E., vol. 27, pp. 41–50; January, (1939).

PART V—RADIO RECEIVERS*

Broadcast Receivers—Communication Receivers—Navigational-Aid Receivers—Measuring Apparatus and Technique—Statistics

Broadcast Receivers

The general use of the loop antenna in broadcast receivers was occasioned primarily by the desire to eliminate the inconvenience of installing a conventional antenna and, secondarily, by the desire to minimize noise interference. Those receivers designed to reduce susceptibility to external noise incorporated an electrostatic shield for the loop. The use of such shielding enhanced the directional properties of the loop by reduction of electrostatic pickup, so that such receivers when of the console type usually incorporated a rotatable loop. Loop rotation controllable from the front of the receiver was used in but few models, however.

The use of the loop was extended to the short-wave band in several models; in others the broadcast-band loop or the shielding thereof was used as an electrostatic-pickup-type antenna on short-wave bands.

Untuned radio-frequency stages were used to improve sensitivity in several models. The untuned stage was usually designed to have substantial gain (6 to 20 decibels) up to approximately 18 megacycles when used with a high-transconductance tube.[1] In other models an untuned intermediate-frequency stage was used.

Untuned antenna circuits using inverse feedback for reduction of cross modulation were employed in some commercially available models.

Receivers appeared on the market incorporating continuous permeability tuning over the entire standard broadcast band. Permeability tuning of the loop circuit by variation of an inductance in series with the loop was used in some models.

Portable receivers using a loop antenna and powered by dry batteries became very popular and because of the use of 1.4-volt filament-type tubes gave good performance with a useful battery life of about 250 hours.

Receivers were introduced which operated from alternating-current, direct-current, or battery power supply, some of which were equipped with relays for automatically transferring from the self-contained batteries to the (rectifier) power-supply unit when plugged into an alternating-current or direct-current outlet.[2]

Many more receiver models than in the past few years incorporated the broadcast band only, thus recognizing that for entertainment purposes the short-wave bands are little used. However, war in Europe increased interest in and the use of short-wave bands on receivers so that while there were fewer models with short-wave bands, actual usage of short-wave bands in receivers increased.[3,4]

Receivers designed for reception of frequency-modulated waves were the subject of much attention during the past year, and several models were placed on the market. These included table models, designed for reception of frequency-modulated waves in the 40-to-45-megacycle band only, as well as console models for reception of this band in addition to amplitude-modulated-wave reception in the broadcast and short-wave bands. Frequency-modulated-wave receivers were generally of the superheterodyne type, using an intermediate frequency between 1.5 and 4.0 megacycles with a band width of approximately 200 kilocycles and embodied amplitude-limiting and frequency-discrimination circuits.[5–7]

A system of reception of frequency-modulated waves was described in which a portion of the output voltage is fed back to the local oscillator to produce frequency modulation thereof in inverse phase. As a consequence the necessary pass band of the amplifier circuits of the receiver is reduced, distortion arising therein minimized, and effects on noise disturbances similar to those obtained by amplitude limiting secured.[8]

The signal-to-noise characteristics of phase-modulated-wave reception were investigated, and it was shown that the signal-to-noise ratio at the ouput of the receiver is equal to the product of the phase deviation in radians and the carrier-noise ratio. A new type of receiver using an off-neutralized crystal filter was described and other methods of phase-modulated-wave reception discussed.[9]

Many different designs of table-model radio-phonograph combinations appeared on the market.[10] The use of automatic record-changers increased greatly. Interest in home recording was revived and new low-priced plastic record blanks became available for this use.[11]

In many receiver models provision was made for

* Decimal classification: R360.

[1] D. G. Fink, "Circuits you'll see tomorrow," *Rad. and Telev. Ret.*, vol. 24, p. 42; June, (1939).

[2] "Triplex-portable principles," *Rad. and Telev. Ret.*, vol. 24, p. 62; October, (1939).

[3] "War revitalizes short waves," *Rad. and Telev. Ret.*, vol. 24, p. 20; October, (1939).

[4] "War stimulates short wave interest," *Rad. and Telev. Today*, vol. 24, p. 14; October, (1939).

[5] J. R. Day, "Receiver for frequency modulation," *Electronics*, vol. 12, pp. 32–35; June, (1939).

[6] G. W. Fyler and J. A. Worcester, Jr., "A noise-free radio receiver," *Gen. Elec. Rev.*, vol. 42, pp. 307–310; July, (1939).

[7] G. W. Fyler and J. A. Worcester, Jr., "A new Armstrong frequency-modulated-wave receiver," *Proc. Radio Club Amer.*, vol. 16, pp. 16–18; July, (1939).

[8] J. G. Chaffee, "The application of negative feedback to frequency-modulation systems," Proc. I.R.E., vol. 27, pp. 317–331; May, (1939); *Bell Sys. Tech. Jour.*, vol. 18, pp. 404–437; July, (1939).

[9] M. G. Crosby, "Communication by phase modulation," Proc. I.R.E., vol. 27, pp. 126–136; February, (1939).

[10] "Compact combinations are hot," *Rad. and Tel. Ret.*, vol. 24, pp. 16–17; October, (1939).

[11] "Recordio," *Rad. and Telev. Ret.*, vol. 24, p. 55; October, (1939).

using the audio-frequency system for television sound. Other models had complete ultra-high-frequency systems, a doubly resonant intermediate-frequency system being employed in some receivers, resonant to 455 kilocycles for broadcast-band reception and to approximately 3000 kilocycles for ultra-high-frequency reception.[1]

A radio receiver appeared on the market which incorporated, in addition to its conventional functions, an oscillator capable of transmitting the received program over power wires to other receivers in the same house equipped with appropriate coupling means to the power lines.[12]

In Great Britain progress in radio receivers was in improvement of tone-control systems and oscillator stability, the use of output stages with higher output, and simplification and improvement of push-button tuning.[13]

A method employing a nonreversible motor for tuning and wave-band switching in connection with magnetically operated clutches was described.[14]

Circuit Trends

A method of compensating for variation in input capacitance of vacuum tubes with bias by simultaneous application of proportional bias to two electrodes was described.[15]

It was pointed out that the effective internal impedance of an amplifier may be either increased or decreased by proper choice of the type of feedback and that impedance-reducing feedback circuits, when applied to audio-frequency power amplifiers, flatten the response and improve loud-speaker damping. Circuits for impedance-increasing feedback have been described also as a means for improving the selectivity of intermediate-frequency amplifiers.[16]

A treatment of the problems of distributed couplings in ultra-high-frequency circuits was developed by applying low-frequency circuit-analysis methods.[17]

The function of the receiver in the broadcast system was described and possible directions of future progress in receivers pointed out.[18]

An investigation of the composite characteristics of broadcast receivers in use today was made with particular reference to characteristics influenced by the existing broadcast transmission system.[19]

The subject of noise interference with radio reception received much attention in this country and abroad. Methods of measuring radio noise were described using noise meters developed especially for that purpose. Instruments have been designed to measure noise in the frequency spectrum from 150 kilocycles to 20 megacycles and also for the ultra-high-frequency range from 20 megacycles to 125 megacycles. Means of controlling radio interference arising in both low- and high-voltage equipment were also described.[20–23]

Measurement and suppression of radio noise in Canada is carried out by the Radio Division of the Department of Transport. In that country thirty-three automobiles carrying special interference-measuring equipment are in use for noise originating in streetcars, electromedical apparatus, and domestic and commercial electrical equipment. The methods of applying appropriate noise suppression to these various types of apparatus have also been described.[24] Methods of reducing interference to broadcast reception caused by electric railways have been studied abroad with particular regard to the efficacy of capacitors in preventing such interference.[25]

Component Parts

Polystyrene insulating material has been used widely for coil forms, capacitor supporting pieces, and as a dielectric, particularly at ultra-high frequencies where its unusually good power factor has proved to be of decided advantage.[26]

Flexible transmission lines having exceptionally low losses up to 300 megacycles were developed through the use of spun-glass or polystyrene insulation.

Spun-glass insulated wire became available, combining low-loss characteristics with noninflammable properties.

The use of fabricated-plate[27] and deep-etched electrolytic condensers increased markedly because of their small size and improved seal.

[12] "Multiplex-superhet," *Rad. and Telev. Ret.*, vol. 24, p. 52; July, (1939).

[13] "The wireless exhibition, 1939: A technical survey," *Wireless Eng.*, vol. 16, pp. 500–510; October, (1939).

[14] "Simplifying press-button tuning," *Wireless World*, vol. 45, pp. 87–88; July 27, (1939).

[15] J. F. Farrington, "Compensation of vacuum-tube input capacitance by bias-potential control," *R.M.A. Eng.*, vol. 4, pp. 13–15; November, (1939).

[16] H. F. Mayer, "Control of the effective internal impedance of amplifiers by means of feedback," PROC. I.R.E., vol. 27, pp. 213–217; March, (1939).

[17] Ronold King, "The application of low-frequency circuit analysis to the problem of distributed coupling in ultra-high-frequency circuits," PROC. I.R.E., vol. 27, pp. 715–724; November (1939).

[18] A. F. Van Dyck, "The radio receiver as part of the broadcast system," *Communications*, vol. 19, pp. 8–11; March, (1939); and pp. 7–9, 44 46; April, (1939).

[19] D. E. Foster, "Receiver characteristics: Special significance to broadcasters," *Communications*, vol. 19, pp. 9–13, 36–37; May, (1939).

[20] C. V. Aggers, D. E. Foster, and C. S. Young, "Instruments and methods of measuring radio noise," PROC. I.R.E., vol. 27, p. 409; June, (1939). (Summary only.)

[21] C. V. Aggers, "Methods of controlling radio interference," PROC. I.R.E., vol. 27, p. 408; June, (1939). (Summary only.)

[22] Jerry Minter, "A noise meter for television frequencies," *Electronics*, vol. 12, p. 21; December, (1939). (Abstract only.)

[23] C. M. Burrill, "Progress in development of instruments for measuring radio noise," *Electronics*, vol. 12, p. 24; December, (1939). (Abstract only.)

[24] H. L. Merriman and F. G. Nixon, "Radio interference—Investigation, suppression, and control," PROC. I.R.E., vol. 27, pp. 16–21; January, (1939).

[25] S. Lemoine, "Using condensers for eliminating interference from electrical tramways," *Wireless Eng.*, vol. 16, pp. 3–5; January, (1939).

[26] "Polystyrene: Its characteristics and application in short-wave equipment," *Wireless World*, vol. 16, p. 297; September, (1939).

[27] "Electrolytic condensers with fabricated plates," PROC. I.R.E., vol. 27, pp. viii, x; January, (1939).

Communication Receivers

In the field of communication receivers the use of crystal-controlled oscillator circuits in superheterodyne receivers was extended.

Receivers appeared on the market designed for dual-channel diversity reception in which two antenna and radio-frequency channels, a single-oscillator circuit, and dual intermediate-frequency channels were incorporated in a single cabinet.

A receiver was described in which regeneration was employed in both radio-frequency and intermediate-frequency circuits to improve sensitivity and selectivity.[28]

Portable communication receivers equipped with compact dry batteries and using 1.4-volt tubes to give improved performance and battery life, became commercially available.

The use of crystal-filter preselector circuits in aeronautical ground-station receivers to permit reception adjacent to a transmitter was described.[29]

Navigational-Aid Receivers

The special problems connected with radio reception for aircraft navigation and landing were the subject of much study during the past year.[30] An instrument landing system was described involving the use of horn radiators at ultra-high frequencies to produce a triangulation effect which delineates both bearing and glide paths on a visual indicator on the airplane.[31–33]

Bearing errors due to abnormal wave polarization in closed-loop direction finders operating at 450 kilocycles were studied and an empirical formula developed permitting calculation of bearing error for any given polarization or angle of arrival of the wave front.[34]

The effects of mountains on radio direction finding in aircraft were studied also.[35]

A study of precipitation-static generation by airplanes in flight has indicated that the interference with radio reception which occurs under certain meteorological conditions is due to corona discharge. A corona-discharge system located at a point on the airplane remote from the receiving antenna has been developed and has led to marked improvement in reception under precipitation-static conditions.[36]

A method of testing radio compasses in laboratory shielded rooms was described utilizing the radio-frequency field from a transmission line.[37]

A theory of the behavior of shielded receiving loop antennas was developed and the effects of shielding on the performance of the loop analyzed.[38]

A study of some of the peculiar properties of automatic direction-finding equipment caused by continuous loop rotation was made.[39]

It was pointed out that the use of nonlinear amplifiers results in improved precision of direction-finding observations.[40]

Radio equipment installed on coastal-harbor craft, such as yachts and fishing vessels, increased during the year more than two to one, bringing the total installations in this class of service to approximately 2000. The volume of telephone traffic in this type of service likewise increased markedly during the year. Equipment for this service which uses a superheterodyne receiver having 10 crystal-controlled reception frequencies and voice-operated switching means[41] was described.

Measuring Apparatus and Technique

An impedance-measuring instrument became available using the parallel-T circuit for measuring both resistive and reactive parallel components at any frequency in the range from 500 kilocycles to 30 megacycles.[42]

An amplifier suitable for amplifying small direct-current and low-frequency transient potentials was described which uses a balanced modulator with an applied carrier. The voltage to be amplified serves to unbalance the modulator and, after amplification as a carrier variation, is rectified in the output circuit.[43]

A simple oscillator circuit was described in which, by means of impedance transformation, the tube impedances are made small relative to those of the tuned circuit. As a result frequency variations inherent in the tube are much reduced. The method described is

[28] McMurdo Silver, "A new communication receiver kit," *Radio*, no. 239, pp. 46–49, 84–85; May, (1939).

[29] P. C. Sandretto, "Some principles in aeronautical ground-radio-station design," Proc. I.R.E., vol. 27, pp. 5–11; January, (1939).

[30] H. H. Willis, "Recent developments in aerial navigation," Proc. I.R.E., vol. 27, p. 416; June, (1939). (Summary only.)

[31] E. L. Bowles, "Aircraft instrument landing research at the Massachusetts Institute of Technology," Proc. I.R.E., vol. 27, p. 409; June, (1939). (Summary only.)

[32] W. L. Barrow and F. D. Lewis, "The sectoral electromagnetic horn," Proc. I.R.E., vol. 27, pp. 41–50; January, (1939).

[33] W. L. Barrow and L. J. Chu, "Theory of the electromagnetic horn," Proc. I.R.E., vol. 27, pp. 51–64; January, (1939).

[34] R. I. Cole, "Errors in closed-loop direction finders caused by abnormal polarization," Proc. I.R.E., vol. 27, p. 609; September, (1939). (Summary only.)

[35] André Busignies, "Study of the effects of mountains in radiogoniometry and of the combined use of radio beacons and radio compasses for radio navigation," Proc. I.R.E., vol. 27, p. 410; June, (1939). (Summary only.)

[36] H. M. Hucke, "Precipitation-static interference on aircraft and at ground stations," Proc. I.R.E., vol. 27, pp. 301–316; May, (1936).

[37] R. J. Framme, "Aircraft radio compasses, principles and testing," Proc. I.R.E., vol. 27, p. 610; September, (1939). (Summary only.)

[38] R. E. Burgess, "The screened loop aerial," *Wireless Eng.*, vol. 16, pp. 492–499; October, (1939).

[39] Jean Marique, "Automatic radiogoniometers: Methods of measuring the time constants of oscillating circuits," *Wireless Eng.*, vol. 16, pp. 121–124; March, (1939).

[40] W. Ross and R. E. Burgess, "Direction finding: Improvement in the quality of observations by the use of non-linear amplifiers," *Wireless Eng.*, vol. 16, pp. 399–401; August, (1939).

[41] J. D. McDonald, "Medium-power marine radiotelephone equipment," Proc. I.R.E., vol. 27, p. 614; September, (1939). (Summary only.)

[42] D. B. Sinclair, "A parallel-T circuit for measuring impedance at radio frequencies," Proc. I.R.E., vol. 27, p. 615; September, (1939). (Summary only.)

[43] L. J. Black and H. J. Scott, "A direct-current and audio-frequency amplifier," Proc. I.R.E., vol. 27, p. 409; June, (1939). (Summary only.)

applicable from audio frequencies to ultra-high frequencies.[44]

Signal-generating and measuring equipment was made commercially available which extended the upper frequency limit of such apparatus to 325 megacycles.

Service equipment, more convenient and reliable to use, was made available employing radio frequencies for receiver testing and checking of components.[45] Several such instruments enable checking of radio-frequency and audio-frequency circuits by tracing the passage of the signal either through or around each stage thereby greatly assisting in identifying the nature and location of the fault.

Rapid means of determining the response characteristics of audio-frequency amplifiers were described, one method involving the associated steady-state phase shift and another method involving the application of square waves.[46,47]

Cathode-ray-oscilloscope circuit-control equipment primarily for observation and analysis of transient phenomena in electrical systems was described.[48]

The problems connected with the use of field-intensity-measuring equipment in automobiles were studied.[49]

Statistics on Broadcast Receivers for the United States[50]

Average List Prices of 1939 Models

All models	$ 56.00
Table models	22.00
Consoles	104.00
Phonograph-radio combinations	115.00
Portables	26.00
Total number models	921

Types of Models

Table models	50%
Console models	17%
Phonograph combinations	22%
Combinations using automatic record changers	5%
Portable models	11%
Models covering broadcast band only	47%
Models with loop antenna	31%
Portables working on power lines as well as batteries	3%
Models equipped with automatic tuning	30%
Models with radio-frequency stages	10%
Average number of tubes	6.6

Manufactured Quantities

Receivers, approximately	9,000,000
Vacuum tubes, approximately	100,000,000
New receiving tube types announced	140

[44] G. F. Lampkin, "An improvement in constant-frequency oscillators," Proc. I.R.E., vol. 27, pp. 199–201; March, (1939).

[45] "Test oscillators," Proc. I.R.E., vol. 27, p. ii; September, (1939).

The number of receiver models is approximately the same as for last year, in fact has shown little change for several years past.

The average list prices show a decrease of about 20 per cent as compared with those for 1938.

The proportion of table models differs little from the previous year but the proportion of console models dropped sharply, with a corresponding rise in phonograph-combination and portable models.

The quantity of receivers and the quantity of tubes manufactured is approximately 50 per cent greater than for 1938 and constitutes an all-time high for radio production in the United States.

The number of new receiving-tube types introduced likewise sets a new record, being more than twice as great as the number introduced last year. The large number of new tube types was occasioned by two factors: the appearance of new and smaller physical forms and the use of higher filament voltages for series operation. Toward the end of the year a movement developed among some of the tube manufacturers towards a preferred list of tube types, intended to supply requirements of all essential functions but without unnecessary duplication.

A number of developments reported during 1938 had their first formal publication in 1939.[51–55]

This report was prepared by the 1939 Technical Committee on Radio Receivers of the Institute of Radio Engineers, the personnel of which follows:

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Lincoln Walsh

[46] Karl Spangenberg and Winslow Palmer, "A phase-shifting device for the rapid determination of audio-frequency amplifier characteristics," Proc. I.R.E., vol. 27, pp. 555–558; September, (1939).

[47] L. B. Arguimbau, "Audio-frequency testing with square waves," *Electronics*, vol. 12, pp. 23–24; December, (1939). (Abstract only.)

[48] G. J. Siezen, "Impulse testing," *Wireless Eng.*, vol. 61, pp. 391–399; August, (1939).

[49] J. H. DeWitt, Jr., and A. C. Omberg, "The relation of the carrying car to the accuracy of portable field-intensity-measuring equipment," Proc. I.R.E., vol. 27, pp. 1–4; January, (1939).

[50] W. MacDonald, "About merchandise," *Radio and Telev. Ret.*, vol. 24, pp. 16–17, 24, 25, 28, 30–31, 35, 36, 39, 60; July, (1939).

[51] V. D. Landon and J. D. Reid, "A new antenna system for noise reduction," Proc. I.R.E., vol. 27, pp. 188–191, March, (1939). (See reference 17 in 1938 report.)

[52] H. B. Fischer, "Remotely controlled receiver for radiotelephone systems," Proc. I.R.E., vol. 27, pp. 264–269; April, (1939). (See reference 32 in 1938 report.)

[53] R. S. Bair, "Ship equipment for harbor and coastal radiotelephone service," Proc. I.R.E., vol. 27, pp. 258–263; April, (1939). (See reference 33 in 1938 report.)

[54] F. E. Terman, R. R. Buss, W. R. Hewlett, and F. C. Cahill, "Some applications of negative feedback with particular reference to laboratory equipment," Proc. I.R.E., vol. 27, pp. 649–655; October, (1939). (See reference 49 in 1938 report.)

[55] G. R. Mezger, "Oscillograph design considerations," Proc. I.R.E., vol. 27, pp. 192–198; March, (1939).

PART VI—TELEVISION*

System Aspects—Transmitters—Receivers

A noticeable increase in television activities was evidenced during the year, both here and abroad. In the United States these activities were particularly stimulated by the inauguration of public program service in the New York area and the introduction of receivers on the market. In England, increased activities were apparent from reports of a large increase in receiver sales; a public service was inaugurated in France, and in Germany public service was anticipated in the early fall. However, most of the European television broadcast activities were apparently stopped later in the year by the outbreak of hostilities.

System Aspects

Theoretical Studies

Fundamental studies of requirements for television transmission were carried out along several different lines. One important aspect of these studies relates to the contrast required to obtain the best reproduction, this contrast being an over-all quantity for the system as a whole and affected by the individual capabilities of the transmitter, receiver, and transmitting medium.[1,2]

Other studies, experimental as well as theoretical, have been concerned with the most efficient use of a given frequency band and deal with such matters as frame-repetition rate, spot size and shape (vertical versus horizontal definition), and with the comparative merits of monochrome, three-color, and stereoscopic television.[3–6]

Investigations continued on circuits and circuit analysis related to television, indicating a better understanding of factors affecting performance.[7–12]

A mathematical analysis was made on the relative merits of vestigial-sideband versus double-sideband transmission,[13] and a theoretical study presented on a method for evaluating phase and amplitude distortion in wide-band systems.[14]

In a German discussion of single-sideband transmission the conclusion was reached that the special vestigial-sideband-shaping filter should be placed in the transmitter.[15]

Standards

In the United States the Radio Manufacturers Association adopted two additional standards, relating to vestigial-sideband transmission and direction of scanning and a recommended practice on polarization of the radiated wave. The most significant of these standards is the one relating to vestigial-sideband transmission, which prescribes unattenuated transmission of the carrier and upper video-frequency sideband, specifies the attenuation characteristic for the lower video-frequency sideband, and contemplates a receiver characteristic that cuts off in linear fashion through the carrier frequency.

These new standards, together with the 14 standards previously adopted, constitute a complete set of primary system standards. They were formally submitted to the Federal Communications Commission by the Radio Manufacturers Association with the recommendation that they be adopted as official standards for television broadcasting in the United States.[16,17] By the end of the year the majority of the television stations in the United States were operating under recommended standards of the Radio Manufacturers Association.

The Television Committee of the Federal Communications Commission, in a report[18] released on November 15, acknowledged recent progress in television broadcasting and recommended liberalization of existing regulations as an aid to further progress in the new art but warned against premature standardization and unlimited commercialization at this time. Transmitters in the New York, Chicago, and Los Angeles areas began regular scheduled service using Radio Manufacturers Association standards.

* Decimal classification: R.583.

[1] I. G. Maloff, "Gamma and range in television," *RCA Rev.*, vol. 3, p. 409–417; April, (1939).

[2] H. E. Kallman, "The gradation of television pictures," *Electronics*, vol. 12, p. 25; December, (1939). (Abstract only.)

[3] Pierre Mertz, "High definition television," *Jour. App. Phys.*, vol. 10, pp. 443–446; July, (1939).

[4] Manfred von Ardenne, "The problem of stereoscopic television," *Teleg.- Fern.- und Funk-Tech.*, vol. 28, p. 26; January, (1939).

[5] A. B. DuMont, "Design problems in television systems and receivers," *Jour. Soc. Mot. Pic. Eng.*, vol. 33, pp. 66–74; July, (1939).

[6] R. L. Campbell, "Flexibility in television systems and automatic synchronizing of television receivers," Proc. I.R.E., vol. 28, p. 45; January, (1940). (Abstract only.)

[7] A. V. Bedford and G. O. Fredendall, "Transient response of multistage video-frequency amplifiers," Proc. I.R.E., vol. 27, pp. 277–284; April, (1939).

[8] H. A. Wheeler, "Wide-band amplifiers for television," Proc. I.R.E., vol. 27, pp. 429–438; July, (1939).

[9] J. M. Hollywood, "Single-sideband filter theory with television applications," Proc. I.R.E., vol. 27, pp. 457–472; July, (1939).

[10] L. S. Nergaard, "A theoretical analysis of single-sideband operation of television transmitters," Proc. I.R.E, vol. 27, pp. 666–677; October, (1939).

[11] J. F. Wentz, "Measuring transmission speed of the coaxial cable," *Bell Lab. Rec.*, vol. 17, pp. 309–313; June, (1939).

[12] P. A. Stromberg, "Nonlinear distortions in television," *Izvestiya Electroprom. Slab. Toka*, no. 2, pp. 50–58; February, (1939).

[13] Stanford Goldman, "Television detail and selective-sideband transmission," Proc. I.R.E., vol. 27, pp. 725–732; November, (1939).

[14] H. A. Wheeler, "The interpretation of amplitude and phase distortion in terms of paired echoes," Proc. I.R.E., vol. 27, pp. 359–385; June, (1939).

[15] R. Urtel, "Remarks on single-sideband transmission in television," *Telefunken*, vol. 20, pp. 80–83; July, (1939).

[16] "Television systems standards," *R.M.A. Eng.*, vol. 3, p. 14; May, (1939); vol. 4, p. 24; November, (1939).

[17] "First report of Television Committee," Federal Communications Commission, May 22, 1939.

[18] "Second report of Television Committee," Federal Communications Commission, November 15, 1939.

Program Service

In the New York area one public program transmission averaged approximately 12 hours per week of entertainment features plus a somewhat greater number of hours of test-pattern transmission.

Much work was done on the development of program-production technique,[19–22] and a systematic study of audience reaction to individual programs is being made. The programs included film presentations, live-talent, studio production, and events such as football games, boxing matches, etc., televised outside the studio and relayed to the main transmitter for broadcasting. In addition to the regular program service in New York City, several other stations in various parts of the United States were active in carrying on technical experiments and in developing program-transmission technique.

Prior to the outbreak of the war the television public service in Great Britain was making substantial progress. Program transmissions had been increased to 21 hours a week, and a second studio and a second mobile unit for outside pickups had been put in service.

Remote and Relay Operation

Programs originating in different parts of New York City somewhat over a mile from the transmitter were sent over ordinary telephone cables equipped with special equalizers and amplifiers.[23]

The problem of phase and amplitude distortion in the New York-Philadelphia coaxial cable was described further,[11] and work was started to extend the frequency range of the cable to allow transmission of signals up to 3 megacycles. Direct reception for rebroadcast purposes was accomplished over a distance of 129 miles from New York to the Albany-Schenectady capital districts.

The German television cable network was extended still further during the year, and plans were published and studies made for adapting it to transmission of signals according to the German 441-line standards.[24,25]

Public Demonstrations—Fairs

Public demonstrations of television systems in operation were featured by several exhibitors at the Golden Gate Exposition and New York World's Fair.[26] Numerous other public demonstrations were given in this country, South America, and Europe.[27,28]

TRANSMITTERS

Development of a new camera tube was announced.[29] This uses a low-velocity electron scanning beam and has been used with improved results under adverse light conditions for program transmissions from the Empire State Building in New York. Reports were made on camera pickup tubes showing attention to this phase of television.[30–33]

A new type portable equipment in suitcase form was developed, manufactured, and put into service in the New York and Los Angeles areas for picking up programs remote from the studios. Some of the cameras for this service use a small iconoscope to make possible a small and lightweight unit.

A continuous-type film scanner and associated equipment was put in operation.[34] Water-cooled high-pressure mercury-vapor lamps were used for television-studio lighting.

In addition to transmitters in scheduled program operation at the end of the year, a number of others were under construction or in experimental operation in several parts of the United States.

Among these were a transmitter utilizing 625 lines at 15 frames per second[35,36] and one in which the vestigial-sideband characteristic was obtained at a low power level.

Antenna improvements were directed toward uniform impedance over the desired band, directivity toward the horizon in the vertical plane, and arrangements suitable for installation on the small space available on top of tall buildings. The antennas on the Empire State[37] and on the Chrysler Buildings in New York are of this type. A "cubical type" of antenna for television transmission was described.[38,39]

[19] W. C. Eddy, "Television lighting," *Jour. Soc. Mot. Pic. Eng.*, vol. 33, p. 41; July, (1939).
[20] A. W. Protzman, "Television studio technic," *Jour. Soc. Mot. Pic. Eng.*, vol. 33, p. 26; July, (1939).
[21] H. R. Lubcke, "An introduction to television production," *Jour. Soc. Mot. Pic. Eng.*, vol. 33, p. 54; July, (1939).
[22] W. C. Eddy, "Miniature staging," *Communications*, vol. 19, p. 22; April, (1939).
[23] C. L. Weis, Jr., "Television transmission over telephone cables," *Bell Lab. Rec.*, vol. 19, pp. 34–37; October, (1939).
[24] F. Strecker, "Telephone, facsimile, and television transmission over wires," *Elek. Tech. Zeit.*, vol. 60, p. 214; February 23, (1939).
[25] A. Köpping, "Problems in transmission of wide-frequency bands over wires," *Fernsehen und Tonfilm*, no. 2, pp. 9–12; February (1939).
[26] D. H. Castle, "A television demonstration system for the New York World's Fair," *RCA Rev.*, vol. 4, pp. 6–13; July, (1939).
[27] "Traveling television exhibit," *Teleg.- Fern.- und Funk-Tech.* vol. 28, p. 288; July, (1939).
[28] F. Schröter, "Two-way television technique," *Telefunken*, vol. 20, pp. 30–50; July, (1939).
[29] Albert Rose and Harley Iams, "Television pickup tubes using low-velocity electron-beam scanning," PROC. I.R.E., vol. 27, pp. 547–555; September, (1939).
[30] H. A. Finke, "A television pickup tube," PROC. I.R.E., vol. 27, pp. 144–147; February, (1939).
[31] R. B. Janes and W. H. Hickok, "Recent improvements in the design and characteristics of the iconoscope," PROC. I.R.E., vol. 27, pp. 535–540; September, (1939).
[32] Harley Iams, G. A. Morton, and V. K. Zworykin, "The image iconoscope," PROC. I.R.E., vol. 27, pp. 541–547; September, (1939).
[33] C. C. Larson and B. C. Gardner, "The image dissector," *Electronics*, vol. 12, pp. 24–27, 50; October, (1939).
[34] P. C. Goldmark, "A continuous type television scanner," *Jour. Soc. Mot. Pic. Eng.*, vol. 33, pp. 12–25; July, (1939).
[35] R. L. Campbell, "Television control equipment for film transmission," *Jour. Soc. Mot. Pic. Eng.*, vol. 33, p. 677; December, 1939).
[36] "Synchronizing-signal generator," PROC. I.R.E., vol. 27, pp. ii, iv; August, (1939).
[37] N. E. Lindenblad, "Television transmitting antenna for Empire State Building," *RCA Rev.* vol. 3, pp. 387–408; April, (1939).
[38] "Cubical antenna," *Gen. Elec. Rev.*, vol. 42, p. 225; May, (1939).
[39] J. Labus, "Compensation of antenna reaction for television transmitters," *Hochfrequenz. und Elektroakustik*, p. 60; August, (1939).

With the continuance of field tests and the beginning of regular schedules of operation, opportunity was available for further propagation studies pertinent to television.[40] The field strengths of television signals from England, France, and Germany.[41,42] were measured at points on Long Island and occasional pictures of some technical interest from London obtained.

In Germany cathode-ray-tube spot scanners were investigated for film scanning and for direct scanning.[28,43–45] Dissector tubes using multipliers were used for film scanning.[46,47] For general service the image iconoscope was favored.[48–50] Mechanical synchronizing equipment was put into operation in England and Germany.[46,51] Television equipment was built for a station in Rome.[52]

Receivers

American Receivers

The models offered for sale used pictures tubes varying from 5 to 20 inches in diameter and the prices varied from approximately $200.00 to upwards of $700.00. Both console and table models were introduced. In some cases the picture tube screen was viewed directly; in other cases, with vertical mounting of tube, the screen was viewed through a tilted mirror. Some receivers had both picture and sound reception, while others had picture reception but required a complementary sound broadcast receiver to provide the loud speaker and part of the amplification for the sound signal. Still other models had not only complete picture and sound reception of the television signal but also included an all-wave broadcast receiver. A special television antenna installation was usually necessary for satisfactory reception.

Technical Characteristics

All the receivers offered for sale were of the superheterodyne type. Fixed-tuned station selectors were universally used, with a manual "fine-tuning control." Most receivers followed the Radio Manufacturers Association practice of using 8.25 megacycles for the sound carrier and 12.75 megacycles for the picture carrier. The most sensitive sets were capable of fully modulating the picture tube with an input signal of about 150 microvolts.

Horizontal dipole antennas were employed (generally with a reflector or director dipole) which were connected to the receiver through a low-loss balanced transmission line.[53,54]

Much attention was given to the design[55] of the radio-frequency selector circuits.

Considerable advance was made in increasing the stability of heterodyne oscillators, ultra-high-frequency circuits, and intermediate-frequency transformers by the application of temperature-compensated capacitors and the use of stryrol forms with iron cores.

Much development work was done in the design of suitable picture intermediate-frequency amplifiers. It was found that resistance-loaded wide-band transformers did not give sufficient attenuation at the sound carriers of the signal channel and of the adjacent channel. It was therefore necessary to use at least two band-pass filters with respective elimination points at the two sound carriers in question. Four stages of picture intermediate-frequency amplification were generally used, and considerable use was made of the newly developed high mutual-conductance low-power-drain amplifier tubes.[56] Both half-wave and push-pull detectors were to be found.

Wide-band (up to 4 megacycles) video-frequency amplifiers were used with linear phase-shift characteristics. A great deal of research was directed toward the development of these amplifiers[57] and the theory[7,8,58] of various types of distortion introduced both in the video-frequency stages and picture intermediate-frequency stages. In particular, it was found that small amounts of either amplitude or phase distortion caused a pair of apparent echoes, one preceding and one folowing the signal.

Automatic brightness control of the picture tube to restore the direct-current component of the signal was generally used.

[40] K. G. MacLean and G. S. Wickizer, "Notes on the random fading of 50-megacycle signals over nonoptical paths," Proc. I.R.E., vol. 27, pp. 501–506; August, (1939).
[41] D. R. Goddard, "Observations on sky-wave transmission on frequencies above 40 megacycles," Proc. I.R.E., vol. 27, pp. 12–15; January, (1939); *RCA Rev.*, vol. 3, pp. 309–315; January, (1939).
[42] D. R. Goddard, "Transatlantic reception of London television signals," Proc. I.R.E., vol. 27, pp. 692–695; November, (1939).
[43] A. Gehrtz, "Development and present status of the television technique," *Europäischer Fernsprechidienst*, no. 51, p. 18; March, (1939).
[44] Kurt Bruckersteinkuhl, "Afterglow of luminescent substances and its influence on the cathode-ray tube spot scanner," *Fernseh A. G.*, vol. 1, p. 179; August, (1939).
[45] A. Schleede and B. Bartels, "On the development of fluorescent screen for cathode-ray tubes," *Telefunken*, no. 81, pp. 100–108; July, (1939).
[46] R. Moller and G. Schubert, "The development of Fernseh television receivers and pickup devices during the year 1939," *Fernseh A. G.*, vol. 1, p. 153–161; August, (1939).
[47] Werner Hartmann, "The image dissector," *Fernseh A. G.*, vol. 1, p. 130; July, (1939).
[48] R. Behne, "The development of the storage tube," *Fernseh A. G.*, vol. 1, p. 134; July, (1939).
[49] H. Knoblauch and G. W. Kluge, "The image-amplifier storage tube," *Telefunken*, no. 81, p. 51–54; July, (1939).
[50] H. Sallow, "Storage-type camera tubes with semiconducting dielectric," *Fernsehen und Tonfilm*, no. 1, pp. 1–4; January, (1939).
[51] G. Wikkenhauser, "Synchronization of Scophony television receivers," Proc. I.R.E., vol. 27, pp. 492–496; August, (1939).
[52] Johannes Schunack, "Televisión pickup equipment for station EIAR in Rome," *Fernseh A. G.*, vol. 1, pp. 102–107; April, (1939).
[53] P. S. Carter, "Simple television antennas," *RCA Rev.*, vol. 4, pp. 168–185; October, (1939).
[54] S. Goldman, "Dipole arrays as television receiving antennas," *R.M.A. Eng.*, vol. 4, pp. 2–8; November, (1939).
[55] G. Mountjoy, "Television signal frequency circuit considerations," *RCA Rev.*, vol. 4, pp. 204–230; October, (1939).
[56] A. P. Kauzmann, "New television amplifier receiving tubes," *RCA Rev.*, vol. 3, pp. 271–289; January, (1939).
[57] S. W. Seeley and C. N. Kimball, "Analysis and design of video amplifiers, Part II," *RCA Rev.*, vol. 3, pp. 290–308; January, (1939).
[58] H. Kallman, "Transient response in television," Proc. I.R.E. vol. 27, p. 613; September, (1939). (Summary only.)

For scanning, saw-tooth current or voltage generators generally employed some form of synchronizable oscillator followed by a wave-form amplifier. Such amplifiers usually contained adjustable wave-shape circuits (linearity controls). For magnetic scanning a damping diode was frequently employed to increase the range of linearity of the horizontal scanning amplifier and a special output tube, the 6AL6G with an 8000-volt breakdown potential, was developed to withstand the high impulse voltages which occur.

All picture tubes used had white screens, and their screen diameters ranged from 5 to 20 inches.[6] Electric and magnetic scanning and focusing were used. It has been found that halation is the most harmful factor in damaging the contrast in picture tubes.[59]

The highest anode voltage used in home receivers was 8000 volts and the lowest about 2000 volts. Receivers were made which would perform satisfactorily on a 50-cycle power-line voltage while receiving a Radio Manufacturers Association standard (60-field) picture.

Those receiver models which required a complementary broadcast receiver for their sound, generally supplied an audio-frequency signal from the television sound detector to the audio-frequency amplifier of the broadcast receiver. However, there also were receivers designed to radiate the sound intermediate frequency and have it picked up in the antenna of a broadcast receiver.

Receivers for picking up television signals from remote-pickup transmitters operating above 300 megacycles were placed in operation.

Safety Precautions

Elaborate precautions were taken to make receivers safe. On the electrical side, cabinet-back interlocks were generally used which operated by breaking the line circuit. In addition to this, a high resistance in the anode lead of the high-voltage rectifier was frequently used to reduce the high voltage in case of an accidential low-resistance load. In connection with the question of picture-tube implosion, bulb shape was considered, safety glass was usually used in front of the screen, and the body of the tube was surrounded by a metal or paper shield.

Receiver Controls

Controls requiring only an initial adjustment during installation and hence segregated on the chassis, generally included picture width, picture height, horizontal centering, vertical centering, horizontal linearity, vertical linearity, and astigmatic control. Controls for the operators' use generally included station selector, fine-tuning control, volume control, tone

[59] R. R. Law, "Contrast in kinescopes," Proc. I.R.E., vol. 27, pp. 511–523; August, (1939).

The horizontal and vertical hold controls were in some cases on the panel and in other cases segregated.

A method of aligning television receivers in production was described in which test signals are supplied from a central source.[60]

Interference in a signal caused by other television transmitters operated at the same frequency was the subject of some study. One investigator[61] concluded that the interfering signal is troublesome unless it is 40 decibels below the level of the desired signal. The Subcommittee on Television Allocations of the Radio Manufacturers Association used 46 decibels for this figure. To reduce the effect of ignition noise, peak limiters were employed. Interference from diathermy apparatus has been objectionable.

Foreign Developments

New and improved models of television receivers were offered for sale in Great Britain. A simple highly directional tilted-wire television antenna was used.[62] High-mutual-conductance secondary-emission tubes were tried out with success, and a careful study of the high-frequency circuits of a television receiver was made.[63] A system for obtaining large pictures in television reception by electromechanical means was described in detail,[54,64–66] and another system using electronic projection tubes was demonstrated.[67]

In Germany, a series of home receivers was developed, both for direct viewing and for projection.[46] Magnetic deflection and focusing with wide-angle tubes were generally used.[68–71] In particular, a standard television receiver was developed as a cooperative effort among the five largest German tele-control, contrast control, brightness control, and focus.

[60] L. J. Hartley, "Production alignment apparatus for television receivers," Proc. I.R.E., vol. 27, p. 612; September, (1939). (Summary only.)

[61] C. N. Smyth, "Continuous-wave interference with television reception," Proc. I.R.E., vol. 27, p. 415, June, (1939). (Summary only.)

[62] "New television aerial," *Wireless World*, vol. 35, p. 206; August 31, (1939).

[63] M. J. O. Strutt, "High frequency mixing and detection stages of television receivers," *Wireless Eng.*, vol. 16, pp. 174–187; April, (1939).

[64] D. M. Robinson, "The supersonic light control and its application to television with special reference to the Scophony television receiver," Proc. I.R.E., vol. 27, pp. 483–486; August, (1939).

[65] J. Sieger, "The design and development of television receivers using the Scophony optical scanning system," Proc. I.R.E., vol. 27, pp. 487–492; August, (1939).

[66] H. W. Lee, "Some factors involved in the optical design of a modern television receiver using moving scanners," Proc. I.R.E., vol. 27, pp. 496–500; August, (1939).

[67] "Baird cinema equipment," *Television*, vol. 12, p. 199; April, (1939).

[68] Johannes Günther, "Generation of saw-tooth currents for magnetic deflection in television tubes," *Fernsehen und Tonfilm*," no. 3, p. 17; March, (1939).

[69] Johannes Günther, "Shape of scanning field in wide-angle cathode-ray tubes using magnetic sweeps in both directions," *Fernseh A. G.*, vol. 1, p.p 88–94; April, (1939).

[70] Theodor Mulert and Herbert Bahring, "Transformer sweep circuit generators," *Fernseh A. G.*, vol. 1, pp. 82–88; April, (1939).

[71] F. Rudert, "Points in design of home receivers," *Fernsehen und Tonfilm*, no. 5, pp, 33–36; May, (1939).

vision firms.[72–81] The picture tube used in this receiver had a flat rectangular face. Other picture-tube developments were also reported.

This report was prepared by the 1939 Technical Committee on Television of the Institute of Radio Engineers, the personnel of which follows:

E. K. Cohan, Chairman

R. R. Batcher	*T. T. Goldsmith, Jr.*
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P. C. Goldmark	*A. F. Murray*

R. E. Shelby

[72] J. G. Weiss, "The German standard television receivers," *Telefunken*, vol. 20, pp. 9–12; July, (1939).
[73] J. G. Weiss, "On the development of the standard television receiver," *Teleg.- Fern.- und Funk-Tech.*, vol. 28, pp. 246–249; July, (1939).
[74] R. Andrieu and F. Rudert, "The standard television receiver E1." *Teleg.- Fern.- und Funk-Tech.*, vol. 28, pp. 249–257; July (1939).
[75] T. Mulert and R. Urtel, "Beam deflection and high-voltage generator in the standard television receiver E1," *Teleg.- Fern.- und Funk-Tech.*, vol. 28, p. 257–264; July, (1939).
[76] Henning Knoblauch and Erich Schwartz, "The picture tube in the standard television receiver," *Teleg.- Fern.- und Funk-Tech.*, vol., 28, pp. 264–269; July, (1939).
[77] P. Deserno and M. Messner, "A testing tool for measuring the frequency characteristics of the standard television receiver," *Teleg.- Fern.- und Funk-Tech.*, vol. 28, p. 267–271; July, (1939).
[78] H. O. Roosenstein, "Television receiving antennae," *Telefunken*, vol. 20, pp. 13–24; July, (1939).
[79] H. O. Roosenstein, "The standard television broadcast receiving antenna," *Teleg.- Fern.- und Funk-Tech.*, vol 28, pp. 271–276; July, (1939).
[80] H. O. Roosenstein, "On the common reception in television," *Telefunken*, vol. 20, pp. 25–29; July, (1939).
[81] Fritz Below, "On the theory of broad-band video-frequency amplifiers," *Fernseh A. G.*, vol. 1, p. 144; July, (1939).

PART VII—FACSIMILE*

Broadcast Facsimile—Point-to-Point Facsimile (Radio, Wire and Cable)

Broadcast Facsimile

In the general field of experimental facsimile broadcasting the rapid expansion of transmission on standard broadcast channels which occurred in 1938 slowed down. Progress in the field during 1939 came chiefly in increased operation of existing equipment by the broadcasters with resulting experience in the techniques and possibilities of the system. There was a growing tendency to utilize ultra-high-frequency channels rather than in the broadcast band during the night. Of the 25 stations licensed or under construction near the close of 1939, almost two thirds were in the ultra-high-frequency band.

The facilities employed by the stations were essentially the same as in the previous year. These were described in the Committee's report for 1938.

In some systems, which were changed from broadcast-band to ultra-high-frequency operation, crystal-controlled adaptors were used in the receivers.

Higher speeds of operation and larger copy sizes were introduced in the last year.[1] Machines were made available for 8½- and 10½-inch paper width, fed at the rate of 2 inches per minute. These scan at 100 lines per inch. The trend is running toward machines wasting a minimum of time between scanning strokes. Automatic synchronization and automatic framing were further developed to permit operation on any source of electric power. Three principal recording processes continued to be used, namely damp-electrolytic, dry-electric, and carbon paper.

Experimental transmissions were carried out successfully using frequency modulation on approximately 40 megacycles.

Some demonstrations of broadcast facsimile were attractions at the New York World's Fair.

In Italy some study was made of facsimile broadcasting with machines patterned after a make used in the United States.[2]

Point-to-Point (Radio)

An improved system using subcarrier frequency modulation[3] was introduced commercially on the New York-London circuit on May 15 and on the New York-Buenos Aires circuit on December 14. Picture-controlled frequency modulation of the audio-frequency subcarrier is employed over standard radio-station equipment normally used for point-to-point program or telephone service. By means of this system distortion encountered on the over-all circuit is substantially minimized under even adverse conditions and linear operation is made possible. Handling speeds have been tripled, along with a noticeable improvement in recorded copy.

For mobile use a duplex type of facsimile unit for handling two-way simultaneous communication on the same channel is now available.[4,5] It contains two drums, one for transmission, the other for reception, using message blanks 8 by 7 inches. Due to its small size and light weight, it may be used between mobile stations in cars, trucks, planes, or other moving vehicles or between these and fixed stations. It is thus suitable for police and military services. Copy may be transmitted at a speed of 8 square inches per minute with a definition of 100 lines to the inch. Synchronized operation is entirely automatic.

* Decimal classification: R583.
[1] "Finch high speed facsimile system," *Electronics*, vol. 12, pp. 61–62; May, (1939).
[2] "Tests on radio facsimile transmission in Italy," *Radio e Televisione*, vol. 3, pp. 309–316; March, (1939).
[3] R. E. Mathes and J. N. Whitaker, "Radio facsimile by subcarrier frequency modulation," *RCA Rev.*, vol. 4, pp. 131–153; October, (1939).
[4] Henry Roberts, "Finch radio facsimile," *Aero Digest*, vol. 36, p. 163; January, (1939).
[5] Robert D. Potter, "Two way facsimile unit developed for aviation," *Science News Letters*, vol. 36, p. 341; November 25, (1939).

French facsimile equipment was installed at the New York World's Fair operating by radio with Paris.[6]

In Canada, a direct radio-facsimile service was established between Montreal and London in connection with the visit of Their Majesties, the King and Queen of England, to Canada and the United States.[7]

Point-to-Point (Wire and Cable)

The use of wire telephotography for news-picture transmission in the United States is increasing. The year 1939 was marked by the elaborate coverage by wire-news-picture service of the visit of the King and Queen.

The wire transmission is carried out, as reported last year, over both a specially engineered private-line network connected between fixed points, and over regular long-distance message-toll circuits. Portable equipment is frequently used.

Studies, both theoretical and experimental, were carried out to check the effectiveness of using vestigial-sideband (or nearly single-sideband) transmission of telephotograph signals. A considerable improvement was reported over double-sideband transmission using the same total available frequency band width.[8] In Germany a study was carried out of direct positive-picture reception, with apparently satisfactory results.[9]

High-quality picture transmission by ocean cable was initiated between London and New York early in the year. The system makes use of the high-speed loaded submarine-telegraph cable from England via Newfoundland to New York. The transmission system is new in ocean-cable practice, with 4 completely electronic repeaters, each of which includes extensive electrical networks to compensate for cable distortion and minimize effects of extraneous interference. The system is noncarrier, utilizing the band from substantially zero frequency to 150 cycles per second. The transmission speed is about 2 square inches per minute. The various news-picture organizations have made extensive use of the new service.

[6] "Proposed new facsimile service to New York Fair," *U. S. Foreign Comm. News*, vol. 13, pp. 148–149; August 11, (1939).
[7] "Canadian Marconi inaugurates trans-Atlantic radio facsimile service," *Tel. and Tel. Age*, no. 1261, p. 133; June, (1939).
[8] H. Nyquist and K. W. Pfleger, "Effect of the quadrature component in single sideband transmission," *Bell Sys. Tech. Jour.*, vol. 19, pp. 63–73; January, (1940).
[9] W. Heintze and H. Schoenfeld, "Reception of positive pictures in telephotographic transmissions," *Elek.-Nach. Tech.*, vol. 16, pp. 87–91; April, (1939).

The application of facsimile to point-to-point message service expanded. In addition to the commercial extension of the facsimile systems and apparatus, a new type of automatic facsimile scanner was developed. This transmitter is designed especially to provide a convenient and rapid method for the collection of telegrams and their delivery to a central office. This machine, known as the automatic telegraph, is only slightly larger than a mail box, and is installed in branch offices, customers' offices, office buildings, hotel lobbies, etc.

The telegram is placed in the machine by the customer or attendant in much the same manner as a letter is dropped into a mail box. At the central office an automatic recorder is used to record the telegram on a dry electrically sensitive recording paper.

In the extension of facsimile to commercial service, this automatic-telegraph method was included in the conversion of a large branch office in New York. A number of these transmitters were also employed at both the New York and San Francisco World's Fairs to handle telegrams originating at these points.

Experiments in facsimile message transmission were also conducted with equipment of the type described above under broadcast facsimile. About 250,000 words of news bulletins were transmitted on this basis by wire from a point in Toronto and received at the Canadian National Exposition. The recorder produced black-and-white copy, using an electrolytic process on slightly moistened paper.

An extensive network of public and private stations was developed in Europe.[10–15]

This report was prepared by the 1939 Technical Committee on Facsimile of the Institute of Radio Engineers, the personnel of which follows:

W. G. H. Finch, Chairman

J. C. Barnes	*George Lewis*
W. A. R. Brown	*P. Mertz*
J. L. Callahan	*J. W. Milnor*
J. V. L. Hogan	*C. J. Young*

[10] "Status of telephotographic connections in Europe," *Siemens Zeit.*, vol. 19, pp. 47–48; January, (1939).
[11] "Introduction of facsimile telegraph letters," *E.F.D.*, p. 216; July, (1939).
[12] "Progress in telephotography," *Elec. Rev.*, (London), vol. 125. p. 433; September 29, (1939).
[13] O. Lemke, "Telephotography for the general public," *Telegraphen Praxis*, vol. 19, pp. 133–135; May 13, (1939).
[14] "Russia makes marked progress in facsimile transmission," *Tel. and Tel. Age*, no. 1267, p. 275; December, (1939).
[15] "Pictures by wire," *Electronics*, vol. 12, pp. 13, 14, 15, 90, 91; September; (1939).

A Wide-Band Inductive-Output Amplifier*

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Summary—*In order to obtain amplification over a wide band of frequencies, a tube having high transconductance and low input and output capacitance is required. A grid-controlled inductive-output tube having these attributes and giving 10 watts output at 500 megacycles is described. A high ratio of transconductance to input capacitance is attained by close cathode-grid spacing and large grid-screen spacing, the latter made possible by use of a very high screen voltage. A low output capacitance is obtained by the use of an inductive-output arrangement which requires no power dissipation by the output electrodes. The design of the output circuit for low inherent capacitance is facilitated by the use of magnetic lenses to focus the electron beam. These lenses can be energized by a permanent magnet. Loading caused by secondary electron emission from the current collector is eliminated. The performance of the tube as a wide-band amplifier is described.*

THE interest in the application of ultra-high frequencies for communication purposes was greatly stimulated by the publication within recent months of several papers describing successful applications of novel principles for generation and amplification of ultra-high-frequency oscillations.[1,2,3] Power outputs of the order of hundreds of watts at frequencies of over 500 megacycles were reported.

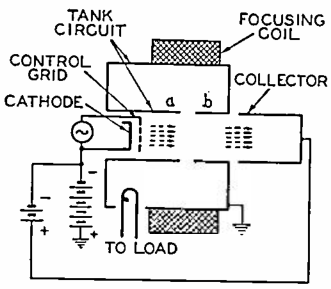

Fig. 1—Schematic diagram of a grid-controlled inductive-output amplifier.

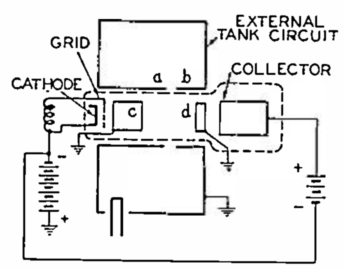

Fig. 2—Diagram of an inductive-output amplifier with an external output circuit.

For certain applications an ultra-high-frequency power amplifier capable of transmitting a wide band of frequencies is required. Thus, to the original requirement of high power output at high frequency a new requirement of band width is added. This additional requirement introduces certain problems which must be considered in the design of ultra-high-frequency tubes for this service. The present paper describes a power amplifier designed especially for wide-band applications at ultra-high frequencies. In order to obtain amplification over a wide band of frequencies a tube having high effective transconductance and low input and output capacitances is required. An analysis of the situation indicated that a grid-controlled inductive-output tube possesses characteristics which make it particularly well adaptable to meet these requirements. In order to make the discussion of the specific problems encountered in the design of this tube more readily understood, the principle of operation of the grid-controlled inductive-output tube will be reviewed briefly.

Fig. 1 illustrates the essential elements of an inductive-output amplifier. An electron stream originates at the cathode, passes through the control grid and the output electrodes *a* and *b*, and is finally collected at the collector electrode. The control grid which is placed near the cathode varies the electron stream when the input circuit connected between the grid and cathode is excited. The output electrodes *a* and *b* surrounding the electron stream form an integral part of the output tank circuit which is excited by the varied electron stream passing through the output gap *a–b* at high velocity. Electrons decelerated in the gap *a–b* by the high-frequency voltage are collected at the low-voltage collector. The load is shown inductively coupled to the tank circuit.

Fig. 2 represents an arrangement in which the output circuit is external to the glass envelope of the tube. In this case the excitation of the tank circuit by the varying electron stream takes place by electric induction through the glass wall of the tube. To avoid undesirable effects of electric charges on the glass the two auxiliary accelerating electrodes *c* and *d*, to which high voltage is applied, are placed within the glass envelope. These electrodes are positioned some distance away from the output gap *a–b* in order to minimize coupling to the output circuit. The screening action of the electrodes *a* and *b* makes it possible to reduce the output-input coupling to a negligible value.

With the general principles of the tube operation in mind, the particular requirements for wide-band amplification can now be considered. The figure of merit of a tube for wide-band service can be defined as the transconductance divided by the geometric mean of input and output capacitances. The first objective, then, is the attainment of high transconductance. The solution is to reduce the grid-cathode spacing to a minimum. Because of the fact that the input capacitance increases in inverse proportion to the first power of grid-cathode spacing, while the transconductance increases as the second power of the spacing, the reduction of spacing results in a net increase of the figure of merit. The use of small spacing which satisfies the requirement of maximum gain also satisfies the high-frequency requirement of minimum transit time. The latter is important in order to avoid excessive input loading and loss in transconductance from finite electron transit time.

In order to obtain sharp cutoff characteristics and to make full use of the cathode area, the turns per

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† Research and Engineering Department, RCA Manufacturing Co., Inc., Harrison, N. J.

[1] A. V. Haeff, "An ultra-high-frequency power amplifier of novel design," *Electronics*, vol. 12, pp. 30–32; February, (1939).

[2] W. C. Hahn and G. F. Metcalf, "Velocity-modulated tubes," Proc. I.R.E., vol. 27, pp. 106–116; February, (1939).

[3] R. H. Varian and S. F. Varian, "High frequency oscillator and amplifier," *Jour. Appl. Phys.*, vol. 10, pp. 321–327; May, (1939).

inch of the grid must be increased in proportion to the reduction in the grid-cathode spacing. Because the grid-wire diameter cannot be reduced indefinitely for mechanical reasons, the μ of the control grid will be high. To obtain sufficient current at negative control-grid potential an intense accelerating field must be established at the control grid by the accelerating electrode. This can be accomplished either by placing the accelerating electrode close to the control grid or by applying a very high voltage on the accelerating electrode. The first alternative is undesirable because the proximity of the accelerating electrode results in an appreciable increase in the capacitance of the control grid. However in conventional tubes this is the only practical solution because of the limitations imposed by the dissipative ability of the screen grid and by the requirements of high plate efficiency. The use of the inductive-output principle and of electron focusing makes it possible to operate the accelerating electrode at a potential of several thousand volts. Thus, the accelerating electrode can be placed at an appreciable distance away from the control grid so that a sufficient field can be established without increase in the control-grid capacitance.

Fig. 3 illustrates the potential-field distribution when an accelerating electrode of cylindrical form is used. To provide uniformity of field at the grid and to focus the beam an aperture disk is placed between the cylinder and the control grid. The control grid is mounted on this disk slightly displaced from the plane of the aperture. This arrangement produces a field uniform over the whole surface of the cathode which results in sharp cutoff characteristics and, thus, increases the effective transconductance under class B operating conditions. The inward radial component of the electric field serves to focus the electron stream initially and, therefore, materially reduces stray current to the accelerating electrode.

With regard to output capacitance, the inductive-output tube has a considerable advantage over conventional tube design. Because the output electrodes do not dissipate energy their size is determined only from the considerations of the cross-sectional dimensions of the electron beam and the electron transit time across the output gap. By making use of a high accelerating potential the electron transit time can be reduced to a fraction of a period even when the gap length is appreciable. As a result, the end capacitance at the gap can be made very small. In some developmental tubes of the inductive-output type this capacitance has been reduced to a fraction of a micromicrofarad. However, one must consider the distributed capacitance of the output circuit. Thus, an output circuit consisting of a uniform concentric line has an effective lumped capacitance equal to one half of the total distributed capacitance. The distributed capacitance depends upon the ratio of the diameters of the inner and outer conductors and is proportional to the length of the line which in turn is proportional to the operating wavelength. The shorter the operating wavelength the smaller the capacitance of the output circuit and, therefore, the broader the circuit for the same impedance. In a properly designed circuit the total effective capacitance can be reduced to a value of the order of 1 to 2 micromicrofarads at a frequency of 500 megacycles.

Because the size of the output electrodes is determined primarily by the cross section of the electron stream, the low output-circuit capacitance is achieved

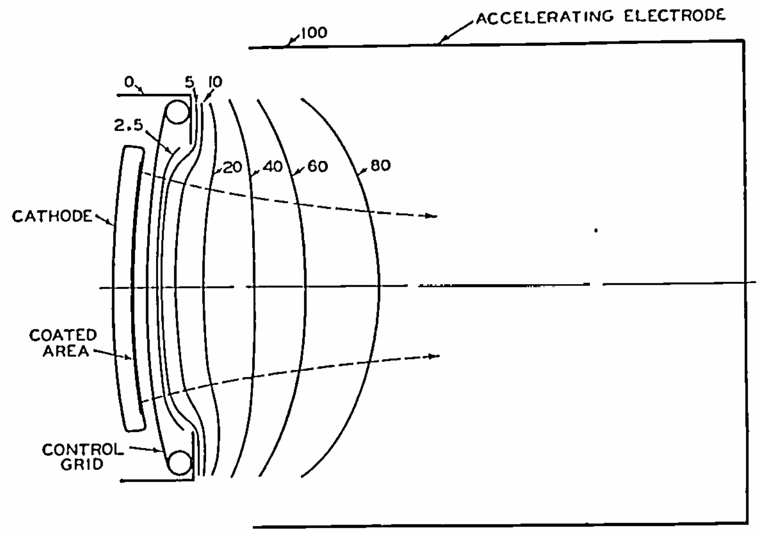


Fig. 3.—Electric-field distribution between the control grid and the accelerating electrode showing beam-converging effect of the aperture disk.

by making the outer conductor of large dimensions. This requirement introduces certain problems with regard to focusing of the beam. As was described previously[1] one effective method of focusing is to produce an intense uniform magnetic field in the direction of the beam. However, in a case where a low-capacitance circuit requiring large dimensions is used the size of the focusing solenoid becomes unduly large. Focusing by electrostatic fields is not always desirable because of the necessity of introducing additional focusing electrodes.

An effective method of focusing, however, is to utilize a system of short magnetic lenses. Before describing this method we shall review first the causes of electron-beam divergence. These are: (1) mutual repulsion of electrons, (2) the defocusing due to static electric fields, (3) the defocusing produced by high-frequency electric fields. The latter effect is quite important in an inductive-output tube since electrons are required to traverse the output gap across which there exists a high potential difference which changes appreciably during the time of electron transit. Fig. 4 shows the potential distribution at the gap formed by two adjacent coaxial cylinders across which there is a difference of potential. When an electron is traveling from left to right (as indicated by path (1) in the figure) and the potential difference is such as to accelerate the electron, the electron first encounters a radial component of electric force towards the center.

After crossing the center of the gap it is acted upon by a radial force tending to remove it from the beam. Under static conditions the net effect is convergence of the beam because the electrons accelerated by the

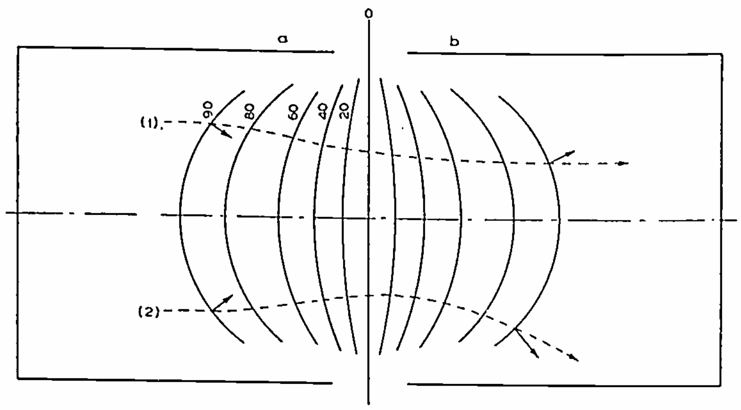


Fig. 4—Potential distribution at the output gap.

axial component of the field will traverse the diverging part of the field in a shorter time than they take to traverse the converging part of the field. However, when the field intensity increases appreciably during the electron transit, divergence may result because the electron experiences an outward force during its transit of the exit side of the gap, which is greater than the force toward the center while traversing the entrance side. This case is illustrated by an electron path (2) in Fig. 4. If the field is decreasing during electron transit the net effect is to converge the beam. When the electron encounters a retarding field at the gap the effects described above are reversed. These considerations show that when the electron transit time across the output gap is appreciable, a very serious divergence or overfocusing of the electron beam may result.

The defocusing due to the variation of electric field with time is overcome most effectively when the magnetic field of the focusing lens occupies approximately the same region as the defocusing electric

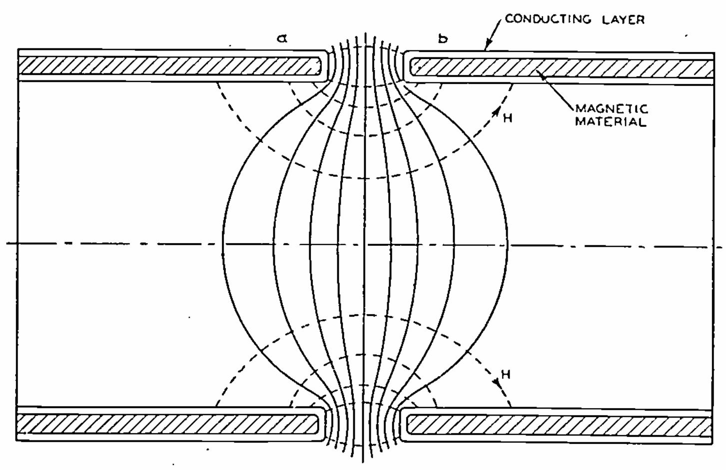


Fig. 5—Magnetic- and electric-field distribution at the lens.

field. Such an arrangement is illustrated in Fig. 5. A magnetic lens made from a ferromagnetic material similar in shape to the conductors producing the electric field is placed close to the output gap. Then the distribution of magnetic field is conjugate to that of the electric field. The magnetic-field intensity can be chosen sufficiently high to produce convergence in spite of the diverging effect of a rapidly changing electric field. In such a lens the force on an electron producing convergence depends on the square of the magnetic-field intensity, which is greater near the beam boundary. Therefore, the outermost electrons will receive the greatest focusing action, so that all electrons passing through the lens will be converged. For this reason a magnetic lens of this type has a very important advantage over a uniform magnetic field. In addition, the localization of the magnetic field in the regions where it is most needed, makes the energy required to establish the requisite field considerably

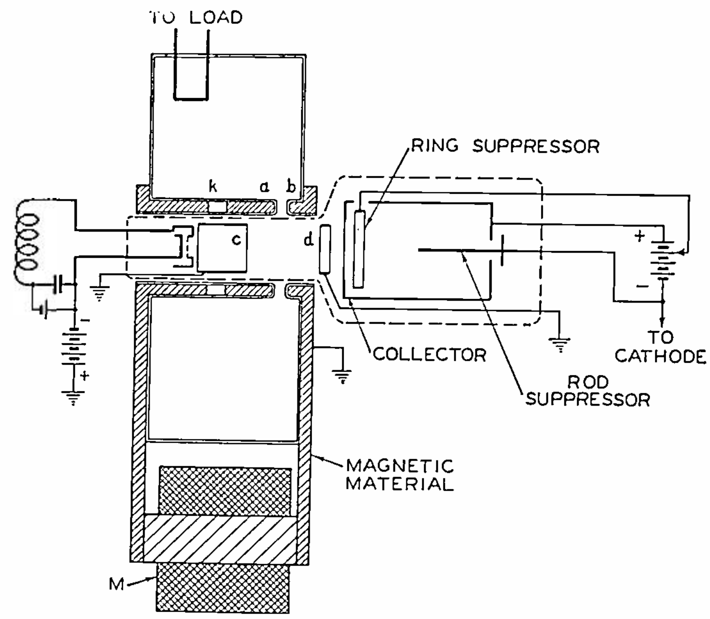


Fig. 6—Complete schematic diagram of the amplifier illustrating the magnetic-circuit arrangement and the disposition of electrodes for secondary-emission suppression.

less than for the uniform magnetic field. This type of magnetic lens is also effective in preventing beam divergence from any cause such as space-charge or the defocusing effect of the electrostatic fields.

In order to avoid losses due to circulating currents induced by high-frequency fields in the ferromagnetic material, it is coated by a layer of material of high electrical conductivity. Because of the skin effect at high frequencies the required thickness of the conducting layer is very small.

A complete arrangement for focusing the beam in the inductive-output tube is shown in Fig. 6. The magnetic circuit of ferromagnetic material is energized by a coil M. Two lenses are formed by the gaps a–b and k in the hollow iron cylinders coaxial with the tube. One of these gaps coincides with the gap in the output circuit. The conducting material of the electrical circuit entirely encloses the iron cylinders forming the magnetic lenses so that all ferromagnetic material is completely shielded from the high-frequency fields. The first lens k prevents the divergence of the beam caused by the accelerating electrode c. The second lens, a–b, compensates for the diverging effect caused by the high-frequency electric field at the output gap. By adjusting the lengths of the gaps a–b and k in the magnetic circuit and by the adjustment of current in the energizing coil M it was possible to prevent electron bombardment of the accelerating electrodes and of the glass walls of the tube. The power required to do this was of the order of 1 to 2 watts, only a small fraction of that needed when a uniform focusing field is used. Because of very low magnetomotive force required to energize the lenses a permanent magnet can be conveniently used for the purpose.

An important characteristic of the inductive-output tube which is particularly advantageous at high power levels, is that high efficiency of operation can be obtained even when operating into a wide-band circuit of comparatively low impedance. This advantage is due to the fact that in an inductive-output tube the functions of output electrode and of current collector are performed by separate electrodes, the potentials of which can be chosen independently.

The wide-band requirement usually results in a tube of high current density and, consequently, of high voltage because of space-charge effects. The ultra-high-frequency requirements of short transit time also necessitate the use of high voltage. However, the wide-band operation requires the use of low-impedance circuits. Therefore the high-frequency output voltage will be comparatively low. If electrons were collected at the potential of the output electrode, a very low efficiency would result. However, in the inductive-output tube the collector potential can be adjusted independently of accelerating potential to a lower value determined primarily by the maximum amplitude of the high-frequency potential across the output gap. This operating condition establishes electric fields near the collector which tend to draw the secondary electrons from the collector towards the active spaces of the tube. The secondary electrons returning to the active spaces tend to abstract energy from the high-frequency circuit and thus reduce the useful high-frequency output power. Furthermore,

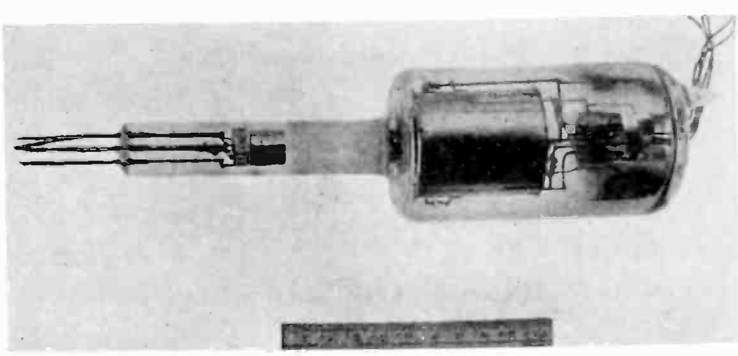


Fig. 7—Photograph of a developmental tube.

these secondary electrons are finally absorbed by the high-potential accelerating electrodes thus increasing their dissipation and loading the high-voltage power supply.

In order to minimize these detrimental effects the secondary emission must be suppressed. This can be accomplished if a suppressing field is established at the surface of the collector. When a strong uniform magnetic field is used for focusing of the beam, an effective suppression of secondaries is obtained if the collector is made with a deep recess as is illustrated in Fig. 1, where a hollow cylindrical collector is shown. The electron beam held from diverging by a strong magnetic field impinges only on the back surface of the collector where the electric field due to the high-potential accelerating electrode is negligibly small because of the screening action of the long cylindrical portion of the collector. Furthermore, the space charge of the beam itself establishes a suppressing field near the surface of the collector thus effectively preventing the escape of secondaries.

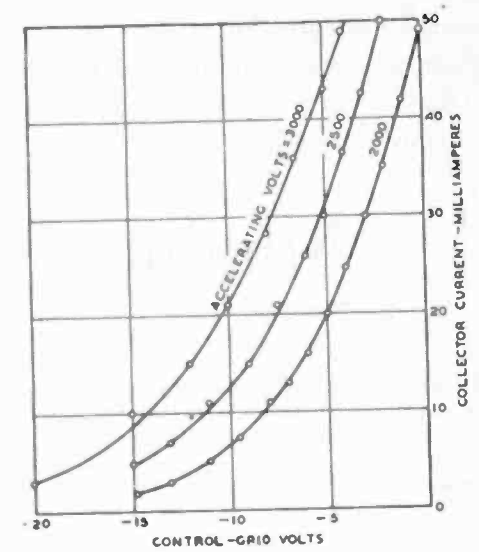


Fig. 8—Static characteristics of a developmental tube.

However, when a system of short magnetic lenses is used for focusing, the above-described means for secondary-emission suppression are not very effective. The reason for this is that electrons may enter the collector region at an appreciable angle to the axis and strike the collector near the entrance where the intense field of the accelerating electrode will draw the secondaries away from the collector.

In order to suppress secondaries it is necessary to establish a suppressing field near the entrance to the collector. An effective arrangement is shown in Fig. 6. Two suppressor electrodes are used, a ring near the entrance and a rod along the axis of the collector. The ring suppresses secondary electrons originating near the entrance and the rod produces a suppressing field over the remaining collector surface. In order to realize maximum collector efficiency, reflections of low-velocity electrons entering the collector must be prevented. Therefore, the ring suppressor is operated at a potential sufficiently low to establish a retarding field at the collector surface but not low enough to depress appreciably the space potential at the entrance to the collector. The rod suppressor electrode, however, can be operated even at cathode potential because electrons entering its suppressing field are deflected toward more positive regions so that no reflections occur. With this type of suppressor electrodes the secondary-emission current was reduced to a value less than 1.5 per cent of the beam current.

A photograph of a developmental tube incorporating principles discussed above is shown in Fig. 7. The cathode, the aperture shield with the grid mounted inside, the accelerating electrodes in the form of cylinders, and the collector with the internal suppressors can be seen. The static characteristics of this tube are shown in Fig. 8. At an accelerating potential of 3000 volts and a beam current of 40 milliamperes a transconductance of 6000 micromhos is obtained. The input capacitance is about 6 micromicrofarads. An output circuit properly designed for this tube for 500-megacycle operation exhibits an effective capacitance of about 2 micromicrofarads. At a frequency of 500 megacycles a power output of 10 watts has been obtained with a power gain of 10 when the tube operates into a circuit loaded to give 10-megacycle band width. The efficiency under this condition was about 25 per cent. At lower power levels, when class A operation is used, a power gain of 20 is obtained.

In conclusion, the advantages of a grid-controlled inductive-output tube for ultra-high-frequency, wide-band operation will be summarized.

(1) High value of transconductance, and low value of input capacitance due to the use of high-voltage accelerating electrodes.

(2) Low output capacitance due to the use of the inductive-output principle.

(3) Good efficiency even with wide-band circuits and at ultra-high frequencies because the collector electrode potential can be adjusted to a value which is approximately equal to the peak value of high-frequency voltage appearing across the output circuit.

Acknowledgment

The authors gratefully acknowledge the valuable contributions to this development of Professor Lloyd P. Smith, of Cornell University, during his association with the RCA Manufacturing Company.

Multiunit Electromagnetic Horns*

W. L. BARROW†, ASSOCIATE, I.R.E., AND CARL SHULMAN†, STUDENT, I.R.E.

Summary—*Composite radiating or receiving systems for ultra-high frequencies may be built with electromagnetic horns as elements that are so positioned and interconnected as to produce the desired characteristics. Several different arrangements are discussed theoretically and experiments made at a wavelength of 8.3 centimeters are described.*

Introduction

THIS paper presents the more important results of an investigation of composite or multiunit radiating systems for ultra-high frequencies having two or more electromagnetic horns as elements. Although suggestions of such combinations of horns have been made in the literature,[1,2] no account of actual experimental or theoretical work appears to have been previously published. Since this field is widely expansive, its extent being limited only by human patience and economics, its more basic aspects only will be treated here.

Multiunit horns operated at ultra-high frequencies have numerous potential applications, including those of aerial and marine navigation, confined or "secret" point-to-point communication, direction, distance, and height indication, and broad-band point-to-point transmission. Features of these radiators include flexibility of operation, electrical steerability, and relatively small length compared to the length of single horns of equivalent effectiveness.

Multiunit horns may conveniently be classified into three broad groups, as illustrated in A, B, and C in Fig. 1. At A, the horn units are connected through transmission lines, and perhaps phase- and amplitude-adjusting means, as in the case of conventional directive antennas; either transmission or reception may

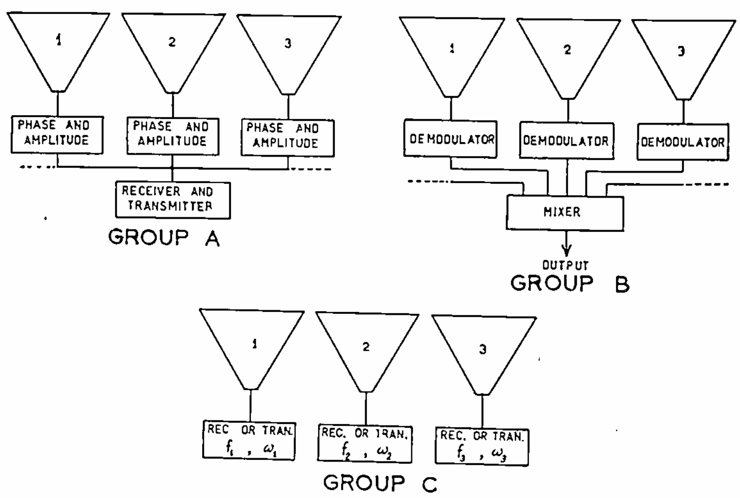


Fig. 1—Broad classification of multiunit horn arrays.

be effected with these systems. Multiunit horns of this group may be referred to as group A horn arrays. The group illustrated by B is mainly useful for reception, the outputs of the individual horns being combined after demodulation. Certain direction-finding applications belong in this group. In the group illus-

* Decimal classification: R129×R111.2. Originial manuscript received by the Institute, November 13, 1939.
† Massachusetts Institute of Technology, Cambridge, Mass.
[1] W. L. Barrow and F. M. Greene, "Rectangular hollow-pipe radiators," Proc. I.R.E., vol. 26, pp. 1498–1519; December, (1939).
[2] G. C. Southworth and A. P. King, "Metal horns as directive receivers of ultra-short waves," Proc. I.R.E., vol. 27, pp. 95–109; February, (1939).

trated at C, the individual units operate at different carrier frequencies $f_{1,2,3}\cdots$ and the modulation frequencies $\omega_{1,2,3,}\cdots$ may be different. There may or may not be an interconnection between the separate receivers or transmitters; the runway localizers of several blind-landing systems would generally fall into this last group. Multiunit horns of the last two groups will be referred to as group B and group C horn arrays, respectively.

Theory of Multiunit Horns

Characteristic of Single Horn

In calculating the radiation or array characteristic E of an array of similar horns, the characteristic of the individual horn elements which comprise the array must be known, either from independent calculation or from measurements. Generally, the absolute magnitude of the electric-field intensity at a large but fixed distance from the array is plotted as the radiation characteristic E; this convention will be adhered

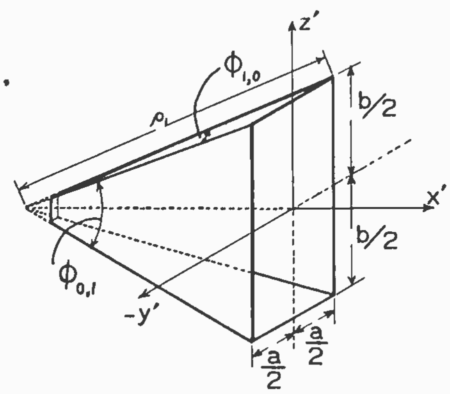
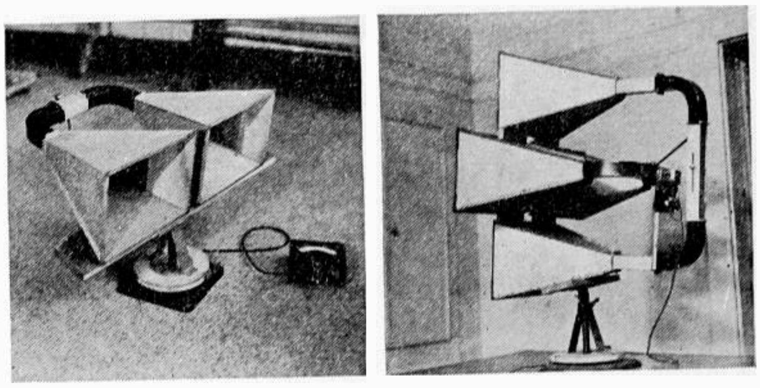


Fig. 2—Pyramidal horn, showing co-ordinate system and dimensions.

to here. The function that defines the element pattern will be termed the "element characteristic" and denoted by F. The element characteristic is generally a complex quantity containing both amplitude and phase of the radiated wave as a function of the space co-ordinates. In certain cases, mathematical expressions may be obtained for it, for example, for hollow-pipe radiators,[1] sectoral and pyramidal horns,[3,4] conical horns, and horns of certain other shapes. The calculation of the array characteristic E may be carried out graphically using measured values for the element characteristic F. Measurements of F for hollow-pipe radiators,[1] sectoral horns,[5] conical horns,[4] and biconical horns[6] are reported in the literature.

In the arrays used in the experimental work described in a following section, the elements were pyramidal horns, as shown in the sketch of Fig. 2 and the photographs of Figs. 3A and 3B. Fig. 2 serves to define the flare angles $\phi_{0,1}$ and $\phi_{1,0}$, the radial length ρ_1, and the mouth apertures a and b. The horn coordinates x', y', z' and the dimensions are also given.



A B

Fig. 3—Experimental horn arrays.

The excitation took place by means of a hollow pipe connected to the throat, the pipe being so dimensioned that only one type of wave was transmitted, namely, the $H_{0,1}$ wave with the electric vector parallel to the y' axis of the horn. This parallel relation between y' and the electric vector will be assumed throughout this paper. The element characteristic for the x', y' plane (F_y) and the x', z' plane (F_z) are reproduced as dotted curves in Fig. 4. They were taken from unpublished data that have been summarized.[4] The solid

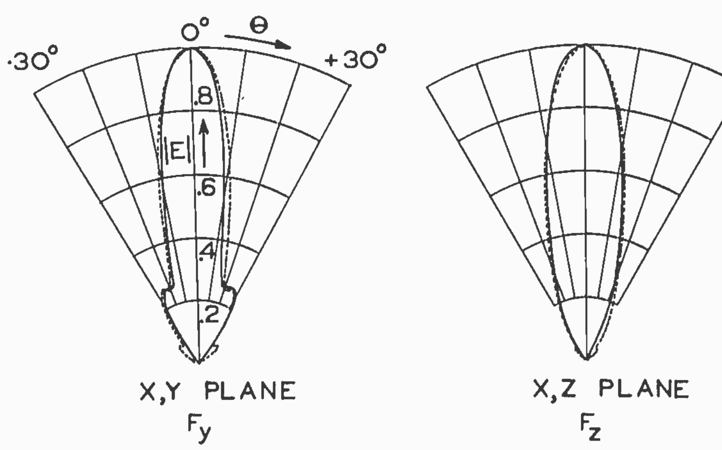


Fig. 4—Radiation characteristics (electric-field intensity versus θ) of the individual horn elements of the arrays. Solid curves show measured data; dotted curves show calculated data.

curve is from measurements described later. Calculations of the experimental arrays were made graphically, using these curves for F.

Planar Array of Horns

It can be shown that the array characteristic E of an array of equally spaced horns whose mouths lie in a plane, the y, z plane of Fig. 5, and whose axes x', y', z' are parallel, respectively, to the space coordinate axes x, y, z is given by the product of the element characteristic F times the "group characteristic" G; i.e.,

$$E = |F \cdot G|. \tag{1}$$

[3] W. L. Barrow and L. J. Chu, "Theory of the electromagnetic horn," Proc. I.R.E., vol. 27, pp. 51–64; January, (1939).

[4] L. J. Chu and W. L. Barrow, "Electromagnetic horn design," *Elec. Eng.*, vol. 58, pp. 333–338; July, (1939).

[5] W. L. Barrow and F. D. Lewis, "The sectoral electromagnetic horn," Proc. I.R.E., vol. 27, pp. 41–50; January, (1939).

[6] W. L. Barrow, L. J. Chu and J. J. Jansen, "Biconical electromagnetic horns," Proc. I.R.E., vol. 27, pp. 769–779; December, (1939).

The group characteristic is a trigonometric function of θ and ϕ and depends on the spacing A/λ and a/λ in wavelengths in the y and z directions, respectively, on the corresponding phase differences B/λ and b/λ, and on the number of elements N, n in the rows. The phase between elements in the z direction differ by b/λ, advancing as z increases. Similarly the phase differs in the y direction by B/λ advancing as y increases. The group characteristic for the case has been given by Southworth[7]

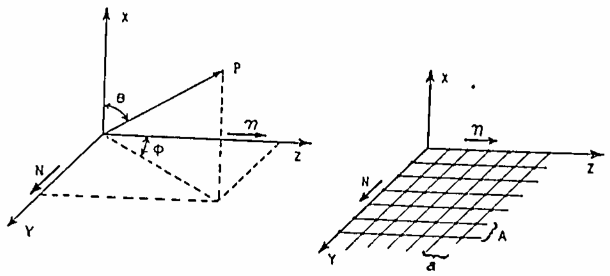


Fig. 5—Co-ordinate systems showing positions of the elements in a planar horn array, and space variables ϕ and θ of the array.

$$G = \frac{\sin \frac{n\pi}{\lambda}(a \cos \phi \sin \theta + b)}{n \sin \frac{\pi}{\lambda}(a \cos \phi \sin \theta + b)} \cdot \frac{\sin \frac{N\pi}{\lambda}(A \sin \phi \sin \theta + B)}{N \sin \frac{\pi}{\lambda}(A \sin \phi \sin \theta + B)} \tag{2}$$

The n and N in the denominators are inserted to make $G=1$ for $\theta=\phi=b=B=0$. By substituting $\phi=0$ degrees into (2), we obtain the group function for the x, z plane, denoted by G_z and similarly for $\phi=90$ degrees we obtain the group function for the x, y plane, denoted by G_y.

Of particular interest is a linear array of n horns ($N=1$), for which the array characteristics in the x, y plane (E_y) and in the x, z plane (E_z) are found to be

$$E_y = |G_y \cdot F_y| = \left| \frac{\sin \frac{n\pi}{\lambda} b}{n \sin \frac{\pi}{\lambda} b} \cdot F_y \right|$$
$$E_z = |G_z \cdot F_z| = \left| \frac{\sin \frac{n\pi}{\lambda}(a \sin \theta + b)}{n \sin \frac{\pi}{\lambda}(a \sin \theta + b)} \cdot F_z \right|. \tag{3}$$

Clearly, in this case the group function has no effect on the shape of the pattern in the x, y plane, but it does have a pronounced effect in the x, z plane. In particular, the angle made with the x axis by the main lobe of the pattern depends on b. This angle of aim may be varied or the beam may be "steered" by changing the phase b between the individual horns.

The opportunity of steering a directed beam from multiple horns offers promising possibilities. For convenience, we have abbreviated the phrase Multiple Unit Steerable Horns, in the manner now fashionable, to the single word MUSH. A simple example of a MUSH will be discussed in more detail in subsequent paragraphs.

In general, if the elements lie on the z axis, E_y is independent of G, and if the elements lie on the y axis, E_z is independent of G. The simplest array has two elements. If these two elements lie on the z axis ($N=1$, $n=2$), the characteristics become

$$E_y = \left| \frac{\sin \frac{2\pi}{\lambda} b}{2 \sin \frac{\pi}{\lambda} b} \cdot F_y \right|$$
$$E_z = \left| \cos \frac{\pi}{\lambda}(a \sin \theta + b) \cdot F_z \right|. \tag{4}$$

Here, too, the shape of the pattern in the x, y plane is given by F_y alone. The pattern in the x, z plane has the same group function as that of two simple antennas, modified by the element function F_z.

The foregoing discussion of horn arrays applies to the combination referred to as group A in Fig. 1, where the outputs of the individual elements are combined at the frequency of transmission, permitting phase interference at the carrier frequency. If the elements are interconnected as indicated in group B of Fig. 1, the phase interference occurs at the frequency of modulations. The expressions for the group characteristic is the same as the one given for group A (equation (2)) except that $\lambda = \lambda_m = C/f_m$, where f_m is the modulating frequency; and b, B correspond to phase differences in the modulating wave. For an infinite value of λ_m, i.e., no modulation, the group characteristic G reduces to unity. For low modulating frequencies, such as audio frequencies, λ_m is so large that G may be considered as substantially equal to unity.

For high modulating frequencies the group characteristic has the same form as it has for A of Fig. 1. A group characteristic of unity means that the response of all the individual elements add algebraically without regard to phase, and the resultant array characteristic is really the sum of the element characteristics.

An interesting combination may be made up according to group B but having horn arrays as the elements which in themselves fall into group A. The resultant array pattern is the sum of the patterns of the element array units A, low modulating frequencies assumed. This type, as was mentioned before, is primarily useful for reception.

Let us consider a special combination, which will be

[7] G. C. Southworth, "Certain factors affecting the gain of directive antennas," Proc. I.R.E., vol. 18, pp. 1502–1536; September, (1930).

described in detail later, where *two* two-horn arrays are interconnected as described above in the preceding paragraph. Let the axis of array I be along the z axis and the xais of array II along the y axis. For array I, $N=1$ and $n=2$, and for array II, $N=2$, $n=1$.

The patterns in the two planes for array I are

$$E_{y_I} = \left| \frac{\sin \frac{2\pi}{\lambda} b}{2 \sin \frac{\pi}{\lambda} b} \cdot F_y \right| \tag{5}$$

$$E_{z_{II}} = \left| \cos \frac{\pi}{\lambda} (a \sin \theta + b) \cdot F_z \right|.$$

The patterns for array II are

$$E_{y_{II}} = \left| \cos \frac{\pi}{\lambda} (A \sin \theta + B) \cdot F_y \right|$$

$$E_{z_{II}} = \left| \frac{\sin \frac{2\pi B}{\lambda}}{2 \sin \frac{\pi B}{\lambda}} \cdot F_z \right|. \tag{6}$$

The resultant pattern of the combination is the sum of those of arrays I and II,

$$E_{y_0} = \left\{ \left| \frac{\sin \frac{2\pi}{\lambda} b}{2 \sin \frac{\pi}{\lambda} b} \right| + \left| \cos \frac{\pi}{\lambda} (A \sin \theta + B) \right| \right\} \cdot F_y$$

$$E_{z_0} = \left\{ \left| \frac{\sin \frac{2\pi}{\lambda} B}{2 \sin \frac{\pi}{\lambda} B} \right| + \left| \cos \frac{\pi}{\lambda} (a \sin \theta + b) \right| \right\} \cdot F_z. \tag{7}$$

This combination can produce a sharp beam of remarkably smooth shape and it can be steered.

A final example from group C arrays will be discussed briefly. Two identical horns with element characteristics F_y, F_z are disposed parallel and in broadside. When both horns transmit with a common unmodulated carrier frequency f_0, the array characteristic is given by (4), from which

$$G_y = \frac{\sin \frac{2\pi}{\lambda} b}{2 \sin \frac{\pi}{\lambda} b}, \quad G_z = \cos \frac{\pi}{\lambda} (a \sin \theta + b). \tag{8}$$

In this example, however, it is assumed that the common carrier f_0 is amplitude modulated at frequency f_1 in horn 1 and at frequency f_2 in horn 2. Reception then takes place with a detector approximately of square-law type, followed by audio-frequency filters that separate the outputs of f_1 and f_2, respectively. Our interest lies in the apparent shape of the radiation pattern in the x, y plane, as thus received, of the independent transmissions at the different frequencies f_1 and f_2. It may be recognized that this situation is found in certain runway localizers for the instrument landing of airplanes and in other radio systems. After some trigonometric manipulation, it may be shown that the apparent array characteristics E_1 and E_2 at frequencies f_1 and f_2, respectively, are given by

$$E_1 = k_1 | F_y \cdot G_y |, \quad E_2 = k_2 | F_y \cdot G_y |, \tag{9}$$

where k_1 and k_2 are constants depending on the percent modulations and the filters. A similar result is obtainable for the x, z plane. We find that the apparent radiation patterns of both horns are identical. We also find that each horn has a radiation pattern of the form of the unmodulated array characteristic (equation (4)) and not that of the single horn. This result may seem striking, but it is readily explained by the interference in space of the synchronized carrier of the adjacent horn with that of the horn in question, which can even produce a vanishing of the carrier for certain angles θ, even though the sidebands of the two horns, being of different frequency, do not interfere.

Mutual Impedance of Horns

In the interconnection of multiunit arrays and their successful operation, the mutual impedance between elements is of considerable importance. The mutual impedance between adjacent parallel horns whose mouth aperture is several wavelengths or more is substantially zero, even though their adjacent edges make actual contact. Horns may therefore be treated as pure self-impedances, from the standpoint of interconnection in circuits. This fact is of considerable value when two or more horns are to transmit independent signals at different frequencies. There is no difficulty in maintaining the pattern of one horn independent of the presence of the other. This situation also holds unabated when the principal axes of the horns are inclined to each other until the angle between the axes is greater than 90 degrees, i.e., until one horn "looks into the other."

Experimental Apparatus and Method

In the series of radiation-pattern measurements to be described in the following paragraphs were made at a wavelength of 8.3 centimeters with apparatus especially developed for horn and hollow-pipe measurements. As used in these measurements, this apparatus comprised the following units: (1) a stabilized magnetron oscillator and its power supply; (2) a pyramidal-horn radiating source connected to the magnetron; (3) a rotating support for the horn under test calibrated in azimuthal angle θ; and (4) the test horn equipped with a calibrated crystal detector. The measurements were carried out by transmitting a steady unmodulated signal from the horn-magnetron source and receiving this signal on the test horn, as indicated by a microammeter, as a function of its orientation. From data obtained in this way, the radiation patterns of E versus θ were plotted.

Fig. 6 shows the transmitting horn, the magnetron source, both of which are mounted on a light wheel carriage with provision for orientation, and the relay rack carrying the magnetron power supplies. The horn is constructed of plywood covered inside with copper foil. It is connected to the magnetron source by a coupling arrangement that permits rapid interchange with other apparatus. The magnetron tube is of the split-anode end-plate type developed by Linder[8] and made available to us through the kindness of B. J. Thompson of RCA Radiotron. Several years of use have proved it to be a very satisfactory source of power when operated with an emission-regulating filament supply, voltage-stabilized anode and end-plate supplies, and a current-regulating magnet supply. The tube is completely inclosed in a cavity resonator of such proportions that the field configuration at the coupling unit is that of the $H_{0,1}$ wave in a rectangular pipe. By this means, a horn wave of similar type having linear polarization is excited. A worm-gear adjustment of the magnetron angle (with respect to the static magnetic field) is provided; its control knob extends outside of the resonant chamber. This equipment can provide, without manual adjustment, a substantially constant radiation field over periods of several hours, which is more than adequate for the purposes at hand.

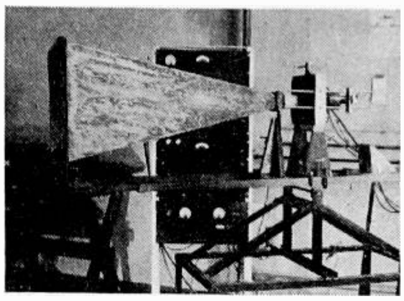


Fig. 6—Photograph of experimental radiation source for 8.3-centimeter waves. The transmitting horn, the magnetron oscillator, and the power-supply rack are shown.

The theorem of reciprocity is invoked to obtain the radiation patterns of arrays of horns from their absorption patterns, following the general procedure also employed by Southworth and King.[2] The separation between radiation source and test horn was about 500 wavelengths, at which distance the transmitting horn could be considered approximately as a point source. The crystal detectors were treated as square-law devices, as roughly verifiable by several different tests. The turntable upon which the test horns were supported for rotation is clearly shown in Fig. 3. Patterns were taken by rotation about the vertical axis. Transmitting horn and test horns were shifted by 90 degrees about their principal axes to obtain both x, y and x, z plane characteristics.

[8] E. G. Linder, "Description and characteristics of the end-plate magnetron," Proc. I.R.E., vol. 24, pp. 633–653; April, (1936).

The individual horns of the arrays were made of galvanized iron sheets spot-welded together, as evident in Fig. 3. This construction has proved to be excellent for small-sized horns. Each horn was separately coupled to a tunable detector unit for taking the individual radiation characteristics shown in Fig. 4. Two horns were interconnected with a hollow conductor of rectangular cross section and of appropriate length dimensions to provide the two- and four-element arrays. A crystal detector with short absorbing rods was mounted within the interconnecting conductor on a tiny brass tube through which the direct-current leads entered. This detector could be longitudinally adjusted to any point along a length of the hollow conductor and could be rotated about its axis through a slit, which is visible in Fig. 3. Rotation of the detector alters the net magnitude of demodulated current and longitudal displacement of it shifts the relative phases of the currents from the two horns. An interesting and perhaps valuable feature of this phase-adjustment means occurs because of the high value of the phase velocity inside the hollow conductor. The frequency, and the dimensions of the conductor are such that the phase velocity is considerably greater than that of light and the wavelength several times greater than the free-space value. The phase shift with longitudinal motion is relatively small and a high precision of phase adjustment or high resolving power is obtained.

In the design of the individual pyramidal electromagnetic horns, it was necessary to determine the radial length ρ_1, the flare angle in the $x'y'$ plane $\phi_{1,0}$, and the flare angle in the $x'z'$ plane $\phi_{0,1}$. The parameters $\rho_1, \phi_{1,0}$, and $\phi_{0,1}$ were chosen to give the optimum beam angle and power gain in the $x'z'$ and $x'y'$ planes. The flare angle $\phi_{0,1}$ determines the beam angle in the $x'z'$ plane, and $\phi_{1,0}$ determines the beam angle in the $x'y'$ plane. In a paper by Chu and Barrow,[4] curves for the design of sectoral horns are given. Although these curves were calculated specifically for sectoral horns, they can be applied satisfactorily to the design of pyramidal horns. The pattern in the $x'z'$ plane of the pyramidal horn is assumed to be the same as that of a sectoral horn having the same polarization, the same values of ρ_1, $\phi_{0,1}$, and the same aperture dimensions. This particular polarization and geometry corresponds to the $H_{0,1}$ wave. Similarly, the pattern in the $x'y'$ plane is assumed to be the same as that of a sectoral horn having corresponding polarization and dimensions. This particular polarization and geometry corresponds to the $H_{1,0}$ wave.

In this investigation the radial length ρ_1 was chosen to be 6 wavelengths (6λ), for convenience in constructions and handling. The following values of $\phi_{0,1}$ and $\phi_{1,0}$ were determined from the design curves:

$$\rho_1 = 6\lambda, \quad \phi_{0,1} = 40°, \quad \phi_{1,0} = 30°.$$

Measurements on Horn Arrays

Two-Horn Array

A series of measurements of the radiation patterns of the two-element array of Fig. 3A will now be described. The electric-intensity vector and the y' axes of the horns were vertical and the z' axes were coincident. The distance between centers at the mouth was 4.8λ. With reference to Fig. 5 and (4), $N=1$, $n=2$.

The shape of the pattern in the x, y plane, i.e., in the vertical plane of Fig. 3A, is independent of the phasing of the horns, although its magnitude does depend on the phase. The pattern in this plane is given by the element characteristic F_y of a single horn. The measured curve is reproduced as Fig. 7. Secondary lobes of very small amplitude might be expected, but they were not detectable in our measurements.

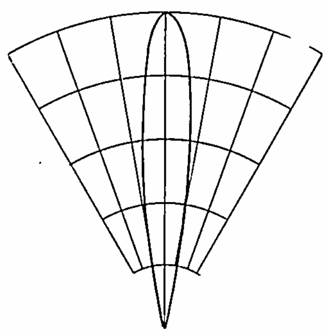


Fig. 7—Radiation characteristic (electric-field intensity versus θ) E_y in x, y plane for the two-horn array of Fig. 3A.

In the x, z plane, i.e., in the horizontal plane of Fig. 3A, the pattern is strongly dependent on the phase relation between the two horns as contained in the group function of (4). A series of eight measured patterns for different phase relations is reproduced as Fig. 8. The absorbing antenna was adjusted near the center of the hollow pipe to a position that afforded substantially zero phase difference. This position was called $l=0$, where l denotes the displacement in centimeters from the zero position. The several patterns of Fig. 8 were taken for different values of l as indicated in the figure. For $l=0$, there is one large lobe at $\theta=0$ degrees and two pairs of similar secondary lobes. The dotted curve on the diagram for $l=0$ represents values calculated from (4) with the data of Fig. 4. The agreement is quite satisfactory. When the phase is varied by changing l in a positive sense, say to $l=+1$, the principal lobe shifts to the left. A change in l in the negative sense shifts this lobe to the right. This trend is clearly visible in the series of curves, which provides an experimental demonstration of the electrical steering of the main beam of a multiunit horn. This two-element array is the simplest form of MUSH. A change in the relative magnitudes of the principal and secondary lobes accompanies the steering action. When the phase is varied by the amount corresponding to $l=-4$, the pattern has radically changed from a single principal beam at $\theta=0$ degrees for $l=0$ to a symmetric double beam with a null at $\theta=0$ degrees. The transition from one shape to the other is continuous and periodic with l.

Another series of measurements similar to those just described have been made for a separation of 7λ between horn centers at the mouth. Only one of these

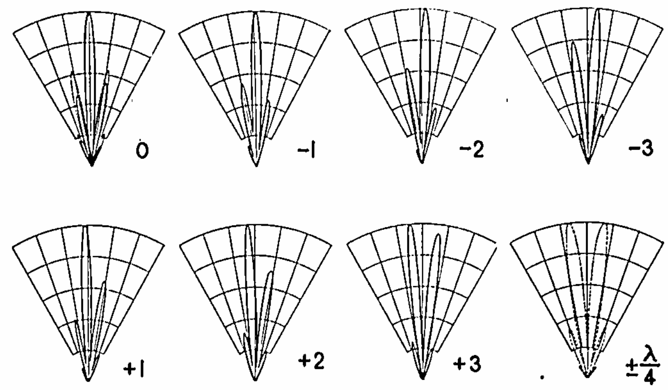


Fig. 8—Radiation characteristics (electric-field intensity versus θ) E_z in x, z plane for the two-horn array of Fig. 3A. The patterns are for different distances l in centimeters of the absorbing rod from the in-phase position $l=0$, as designated by the numbers. Solid curves are measured, dotted curves are calculated.

patterns is reproduced here in Fig. 9. It is evident that the effect of the increased spacing is to squeeze the pattern together in the θ direction, which results from the modified group function, and thereby to produce more lobes.

As a final example of experimental measurements on a multiunit horn, let us consider the four-horn array shown in Fig. 3B. It comprises the two-horn array of Fig. 3A and a second two-horn array whose array axis is at right angles with that of the first array. The two

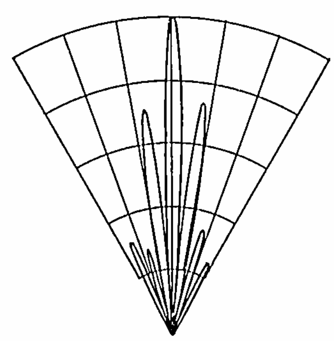


Fig. 9—Radiation characteristic (electric-field intensity versus θ) E_y' in x, y plane for a two-horn array of increased spacing between elements (see text).

arrays have independent detectors and the outputs may be combined in any of several ways. For one thing such a four-horn array may produce relatively sharp and smooth beams by having one of the two-horn patterns reinforce the main lobe of that of the other without a corresponding reinforcement of secondary lobes. As operated in these reported experiments, the resultant radiation pattern was almost exactly the algebraic sum (or difference) of the two individual patterns. The theory of this combination was discussed in connection with (7). The curves reproduced as Fig. 10 show the resultant characteristics in the x, y and the x, z planes

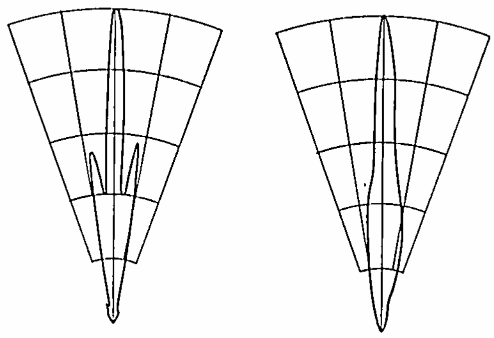


Fig. 10—Radiation patterns (electric-field intensity versus θ) E_y and E_z for the four-horn array of Fig. 3B.

for an additive connection of the direct-current outputs. Some consideration and comparison of these patterns with those of two-horn arrays shows that a definite improvement has been obtained by partially suppressing the secondary lobes.

The array described in the above paragraph was operated as a direction finder in azimuth and elevation, i.e., to locate the direction in space to an unknown source. Separate direct-current meters on each two-horn array, as well as a single meter for both arrays, were used. A remarkably sharp indication was obtained. By using each two-horn array as a split-beam device (Fig. 8, $1=-4$), the resolution was greater than could be maintained or read by the available orientation table, being some small fraction of a degree. The possibilities of multiunit horns in direction finding and "obstacle" detection appear tremendous.

It is desirable to point out the broad-band features of multiunit horns. In the two-horn array of Fig. 3A, for example, each horn element acts as a substantially perfect match for the other and the pickup or exciting antenna is free from reflection effects. Consequently, its frequency-response characteristics are relatively flat.

Note on Modulation*

J. G. BRAINERD†, MEMBER, I.R.E.

Summary—*It is shown that the usual nonperiodic solution of*

$$\frac{d^2y}{dt^2} + \epsilon(1 + k \cos t)y = 0$$

can always be interpreted in the stable case as a wave undergoing simultaneous phase and amplitude modulation. An analysis is carried through on this basis.

IN STUDIES of modulation, superregeneration, simple circuits with a varying parameter, and elsewhere, the following equation

$$\frac{d^2y}{dt^2} + \epsilon(1 + k \cos t)y = 0 \tag{1}$$

has occurred. In (1) y is the dependent and t the independent variable and ϵ and k are parameters. In cases of interest here y may be current, charge, or other quantity in a portion of a circuit, t will usually be directly proportional to time, and ϵ and k will depend on parameters of the electric circuit which are independent of y and t. The equation, however, has an importance independent of the problem to which it may apply. It represents one of the simplest cases of a periodically varying parameter, hence any extension of its analysis may contribute to the solution of more-complicated instances of varying parameters.

For special values of ϵ and k, the solution of (1) is periodic. Such solutions have been studied extensively, some tables of them have been published, and others are being prepared. However, in most technical applications of (1) the parameters ϵ, k are specified in advance, and the solution will not be periodic. In the latter case only first steps have been taken toward making solutions conveniently available.

To give a background to the present discussion certain classical results and others more recently obtained will be summarized:

(a) Any solution of (1) may be written

$$y = C_1 g + C_2 h \tag{2}$$

where C_1 and C_2 are constants, g is that particular solution of (1) satisfying the initial conditions $g(0)=1$ and $g'(0)=0$ (derivatives will be indicated by primes), and h is the particular solution satisfying $h(0)=0$ and $h'(0)=1$. If g is known for $0 \leqq t \leqq 2\pi$, h can be determined in the same interval. If both g and h are known for $0 \leqq t \leqq \pi$, then g and consequently h can be determined in the interval $0 \leqq t \leqq 2\pi$. Methods of obtaining g and h for $0 \leqq t \leqq \pi$ are gradually being developed.

(b) Any solution of (1) may also be written

$$y = C_3 e^{i\mu t}\phi(t) + C_4 e^{-i\mu t}\phi(-t) \tag{3}$$

where the C's are constants, ϕ is periodic with period 2π (as is $\cos t$ in (1)), and μ is the characteristic exponent, a parameter independent of t.

(c) The characteristic exponent μ may be determined in several ways, one of which is by

$$\cos 2\pi\mu = g(2\pi) = h'(2\pi) \equiv b. \tag{4}$$

(d) When μ is real and not an integer, the solution is said to be stable. The function ϕ is then complex; if u_1 and u_2 are defined by

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$$\frac{\phi(t)}{\phi(0)} \equiv u_1 + ju_2 \tag{5a}$$

and

$$\frac{\phi(-t)}{\phi(0)} \equiv u_1 - ju_2 \tag{5b}$$

then u_1 and u_2 are periodic with period 2π. The functions u_1 and u_2 satisfy the equations

$$u_1'' + (\epsilon - \mu^2 + \epsilon k \cos t)u_1 = 2\mu u_2' \tag{6a}$$

$$u_2'' + (\epsilon - \mu^2 + \epsilon k \cos t)u_2 = -2\mu u_1' \tag{6b}$$

which are closely similar to the equations of a coupled (electric) circuit containing equal inductances and varying capacitances, and which are similar to the equations of a physically conceivable electromechanical system. It is worthy of note that (6) does not in general have periodic solutions, but for special values of the parameters the solutions may be periodic. The u functions given below (Figs. 2 and 4 to 8) are in the latter category, since they are periodic.

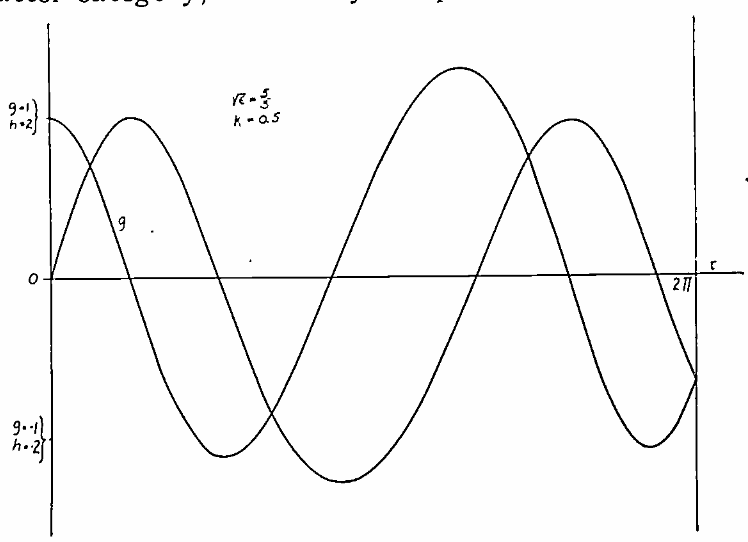


Fig. 1—The g and h solutions of equation (1) for $\sqrt{\epsilon}=5/3$ and $k=0.5$.

(e) The functions g and u_1 are even about $t=0$; the functions h and u_2 are odd about $t=0$; u_1 is even and u_2 is odd about $t=\pi$.

If the u functions defined in (d) and the g and h functions defined in (a) are used in the equation of (b), then after some algebraic manipulation the following equations can be obtained:

$$g = u_1 \cos \mu t - u_2 \sin \mu t \tag{7a}$$

and

$$H \equiv \frac{\sqrt{1-b^2}}{h(2\pi)} h = u_1 \sin \mu t + u_2 \cos \mu t \tag{7b}$$

or

$$u_1 = H \sin \mu t + g \cos \mu t \tag{8a}$$

and

$$u_2 = H \cos \mu t - g \sin \mu t \tag{8b}$$

where it is to be understood that u_1, u_2, g, h, and H are functions of t.

Equations (7) may be written

$$g = U \cos (\mu t + \theta_U) \tag{9a}$$

and

$$H = U \sin (\mu t + \theta_U) \tag{9b}$$

where $U \equiv (u_1^2 + u_2^2)^{1/2}$ and $\theta_U \equiv \tan^{-1} (u_2/u_1)$.

Equations (9) are basic for the present purpose. They show that each g and H solution of (1) can be represented as a sine wave, both the magnitude and phase angle of which are varying and periodic. If the magnitude of a sine wave varies periodically and the frequency and phase angle remain constant, amplitude modulation occurs; likewise if the amplitude and frequency of a sine wave remain constant and the phase

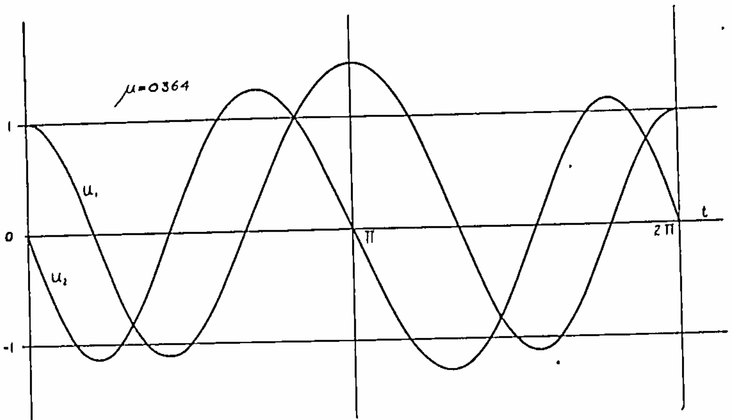


Fig. 2—The periodic u functions for $\sqrt{\epsilon}=5/3$, $k=0.5$, and $\mu=0.364$.

angle varies periodically, phase modulation occurs. Hence g and H represent cases of simultaneous amplitude and phase modulation. The amplitude U has a period 2π and the phase angle θ_U has the same period. In consequence g and H, which are nonperiodic except in special cases, may be considered a sine wave of period $2\pi/\mu$ which is undergoing simultaneous amplitude and phase modulation in which both the amplitude and the phase angle are varying periodically with period 2π.

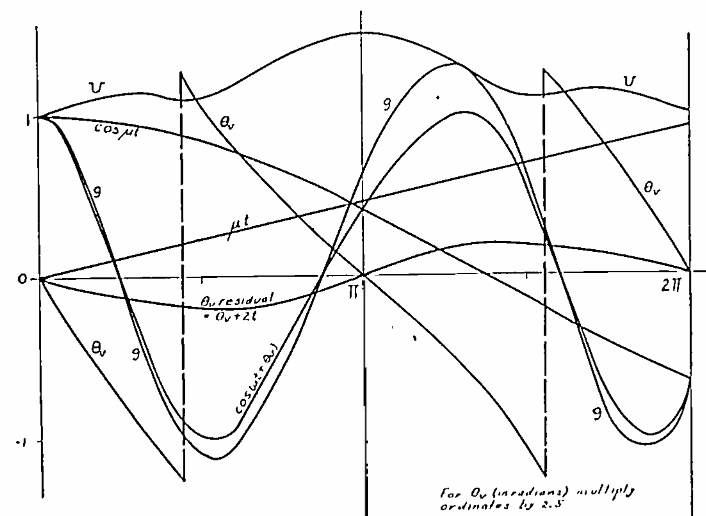


Fig. 3—Components of $g=U \cos (\mu t+\theta_U)$.

In Fig. 1 are shown g and h in the interval $0 \leqq t \leqq 2\pi$ for the particular case[1] in which $\epsilon=(5/3)^2$ and $k=0.5$ in (1). From the figure it is seen that the value of g at $t=2\pi$ is in the neighborhood of -0.6; obtained more accurately from the original g is -0.6572. By (4) it follows that a corresponding value of μ is 0.364. Fig. 2 shows the accompanying u curves, which were obtained by means of (6) but which can be obtained

[1] A small value of ϵ has been chosen for the sake of clarity. For large values of ϵ the g and h curves resemble higher-frequency waves which have undergone double modulation.

directly from the g and h curves by (8). Fig. 3 shows U and θ_U, plotted from the u curves, and also shows the evolution of g from the U and θ_U curves and $\cos \mu t$.

Having synthesized g from U, θ_U and $\cos \mu t$, and thus obtained the doubly modulated nonperiodic resultant from the periodic parts, it seems desirable to investigate some of the other combinations of periodic quantities which will give the same g. The fact that

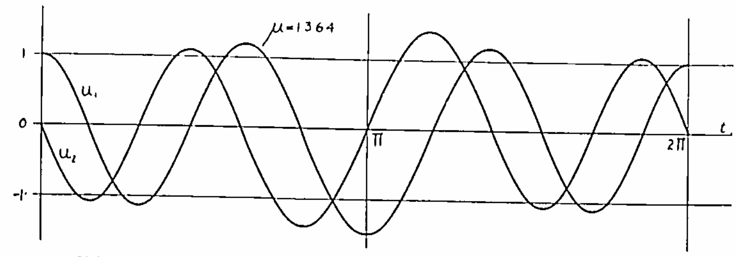


Fig. 4—The periodic u functions for $\mu=0.364+N$ where $N=1$.

u_1 and u_2 are not unique for any given ϵ, k combination follows from the fact that μ is not unique, as (4) shows. The value of μ given above ($\mu=0.364$ when $\epsilon=(5/3)^2=2.78$ and $k=0.5$) can have any positive or negative integer added to it without disturbing (4). Figs. 4 and 5 show the functions u_1 and u_2 which accompany various values of $\mu=0.364+N$ (N a positive integer) and Figs. 6, 7, and 8 show the u functions when $\mu=0.364+N$ (N a negative integer).

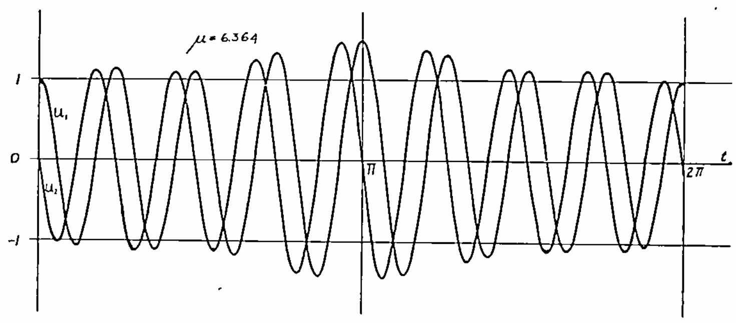


Fig. 5—The periodic u functions for $\mu=0.364+N$ where $N=6$.

It thus appears that for a given ϵ and k there are numerous pairs of u functions, which, when any is used with the value of μ to which it corresponds, will yield the same g and H by (7). The interpretation of the modulation from the u curves is slightly indefinite because of the lack of uniqueness of the u pair corresponding to a definite ϵ, k.

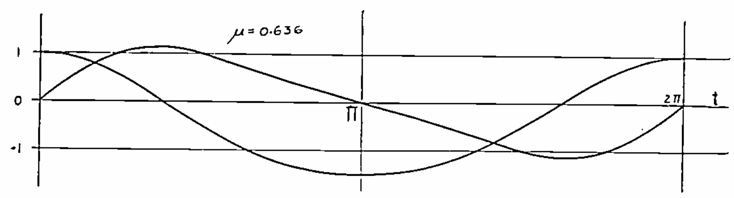


Fig. 6—The periodic u functions for $\mu=0.364+N$ where $N=-1$.

It is possible however to obtain a relatively good definiteness in the functions which go to make up the solution of (1). From (9),

$$U^2 = g^2 + H^2 \tag{10a}$$

and

$$\theta_U = \tan^{-1}(H/g) - \mu t. \tag{10b}$$

Thus for given values of ϵ, k in (1) (and hence definite curves for g and H), the function U is independent of the value of μ used, i.e., independent of whether some value μ_0 corresponding to the given ϵ, k or μ_0+N is used. It has previously been shown that U is periodic (period 2π) and it follows from the definition of $U\equiv(u_1^2+u_2^2)^{1/2}$ that it is even about $t=0$ and about $t=\pi$.

From (10b) it is seen that θ_U varies with μ in a simple manner. Writing μ_0+N for μ,

$$\theta_U = \tan(H/g) - (\mu_0 + N)t, \tag{11}$$

whence the change in θ_U when μ_0+N is used in place of μ_0 is $-Nt$.

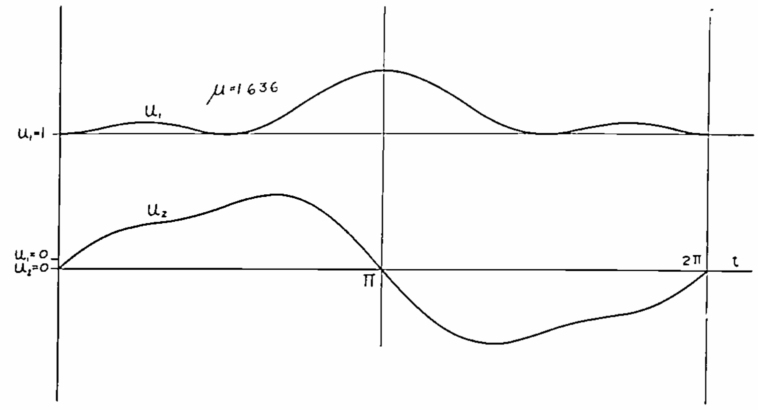


Fig. 7—The periodic u functions for $\mu=0.364+N$ where $N=-2$.

Any θ_U curve can thus be reduced to its "fundamental" or residual form by subtracting Nt from each ordinate, where N is suitably chosen. For example, in Fig. 3, θ_U ranges from 0 to -4π when t varies from 0 to 2π (the variation has been shown on the curve sheet between limits $\pm\pi$ for convenience). This indicates that N might well be taken as -2; θ_U then be-

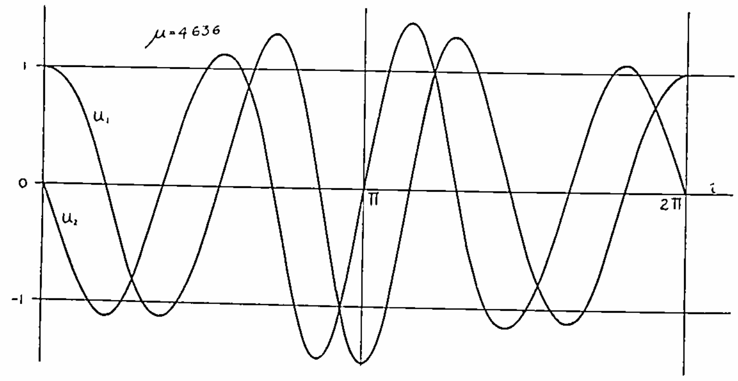


Fig. 8—The periodic u functions for $\mu=0.364+N$ where $N=-5$.

comes the residual curve shown, and this with U given in the figure, and $\mu=0.364-2.000=-1.636$ will probably allow the interpretation of any solution of (1) to be viewed in as simple manner as possible. It has been demonstrated above that θ_U is periodic with period 2π; and that it is odd about $t=0$ and $t=\pi$ is a consequence of its definition.

The preceding analysis has been devoted to reviewing the component parts of the total result. The general solution of (1) can, by (2), be written

$$y = C_1 g + C_2' H \tag{2a}$$

where $$C_2' \equiv C_2 h(2\pi)/(1-b^2)^{1/2}.$$
This in turn can be written, using (9),
$$y = CU \cos (\mu t + \theta_U - \delta)$$
where $$C \equiv (C_1^2 + C_2'^2)^{1/2}$$
and $$\delta \equiv \tan^{-1}(C_2'/C_1).$$
Thus any stable solution of (1) is a constant C multiplied by the U function, an example of which is given in Fig. 3, and by the function $\cos (\mu t + \theta_U - \delta)$ which, without the constant phase displacement δ, is also shown.

Making first approximations for U and θ_U thus,
$$U = U_0 - U_1 \cos t \qquad (12a)$$
$$\theta_U = -Nt + \theta_1 \sin t \qquad (12b)$$
$$\mu = \mu_0 + N \qquad (12c)$$
where U_0, U_1, and θ_1 are constants and μ_0 is the value of μ corresponding to the residual value of θ_U, the general solution y becomes
$$y = C\,({}_0 - U_1 \cos t) \cos (\mu_0 t + \theta_1 \sin t - \delta). \qquad (13)$$
This can be reduced to
$$\begin{aligned} y = C \cos (\theta_1 \sin t)\{ U_0 \cos (\mu_0 t - \delta) \\ - \tfrac{1}{2} U_1[\cos (\mu_0 t + t - \delta) + \cos (\mu_0 t - t - \delta)]\} \\ - C \sin (\theta_1 \sin t)\{ U_0 \sin (\mu_0 t - \delta) \\ - \tfrac{1}{2} U_1[\sin (\mu_0 t + t - \delta) + \sin (\mu_0 t - t - \delta)]\} \qquad (14) \end{aligned}$$
which gives the modulation in what appears to be as near an approach to the expressions used in cases of single modulation as can be obtained. The sine of sine functions $\cos (\theta_1 \sin t)$ and $\sin (\theta_1 \sin t)$ are sometimes expressed as a series of Bessel functions, but they seem simpler in the original form. Certain results which have previously been obtained by others can be deduced from (14) by assuming particular values for the constants θ_1, U_0, U_1, δ.

A more-exact analysis in which U and θ_U are expressed by Fourier series will lead to numerous terms each of the type shown in (14).

Bibliography

The results summarized in (a) to (e), including equations (2) to (6), are taken from Whitaker and Watson, "Modern Analysis," Chapter XIX, and from Brainerd and Weygandt, "Solutions of Mathieu's equation-I," which will be published soon in the *Philosophical Magazine*. The latter contains a bibliography in which are included references to uses of (1) in studies of modulation, superregeneration, varying-parameter circuits, and in numerous other physical problems.

Characteristics of the Ionosphere at Washington, D.C., January, 1940, with Predictions for April, 1940*

T. R. GILLILAND†, ASSOCIATE, I.R.E., S. S. KIRBY†, ASSOCIATE, I.R.E., AND N. SMITH†, NONMEMBER, I.R.E.

DATA on the critical frequencies and virtual heights of the ionospheric layers during January are given in Fig. 1. Fig. 2 gives the monthly average values of the maximum usable frequencies for undisturbed days, for radio transmission by way of the regular layers. The F_2 and F layers ordinarily determined the maximum usable frequencies during the day and night, respectively. Fig. 3 gives the distribution of hourly values of F and F_2 critical-frequency data about the undisturbed average for the month. Fig. 4 gives the expected values of the maximum usable frequencies for radio transmission by way of the regular layers, average for undisturbed days, for April, 1940.

Ionospheric storms and sudden ionospheric disturbances are listed in Tables I and II, respectively. Several extremely mild disturbances of the ionospheric storm type were observed but not included in Table I. As during last month the ionospheric storms were mild and not numerous, and their effects on high-frequency radio transmission were not great. During the past several years it has been observed that for a given degree of magnetic-storm disturbance, the ionospheric-storm disturbance is less during the winter day than at any other time. The sudden ionospheric disturbance of January 8 was severe. Prolonged periods of low-

TABLE I

IONOSPHERIC STORMS (APPROXIMATELY IN ORDER OF SEVERITY)

Day and hour E.S.T.	h_F before sunrise (km)	Minimum $f_F{}^0$ before sunrise (kc)	Noon $f_{F_2}^0$ (kc)	Magnetic character[1] 00–12 G.M.T.	12–24 G.M.T.	Ionospheric character[2]
January 11 (0000 to 0700)	480	diffuse	—	0.7	1.1	0.4
3 (1000 to 1900)	317	1400	8000	0.6	1.5	0.2
4 (0100 to 0700)	300	2600	—	0.6	1.0	0.2
19 (0000 to 0700)	342	1900	—	0.6	0.3	0.2
For comparison: Average for undisturbed days	296	3000	9470	0.3	0.4	0.0

[1] American magnetic character figure based on observations of seven observatories.
[2] An estimate of the severity of the ionospheric storm at Washington on an arbitrary scale of 0 to 2, the character 2 representing the most severe disturbance.

* Decimal classification: R113.61. Original manuscript received by the Institute, February 13, 1940. 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.

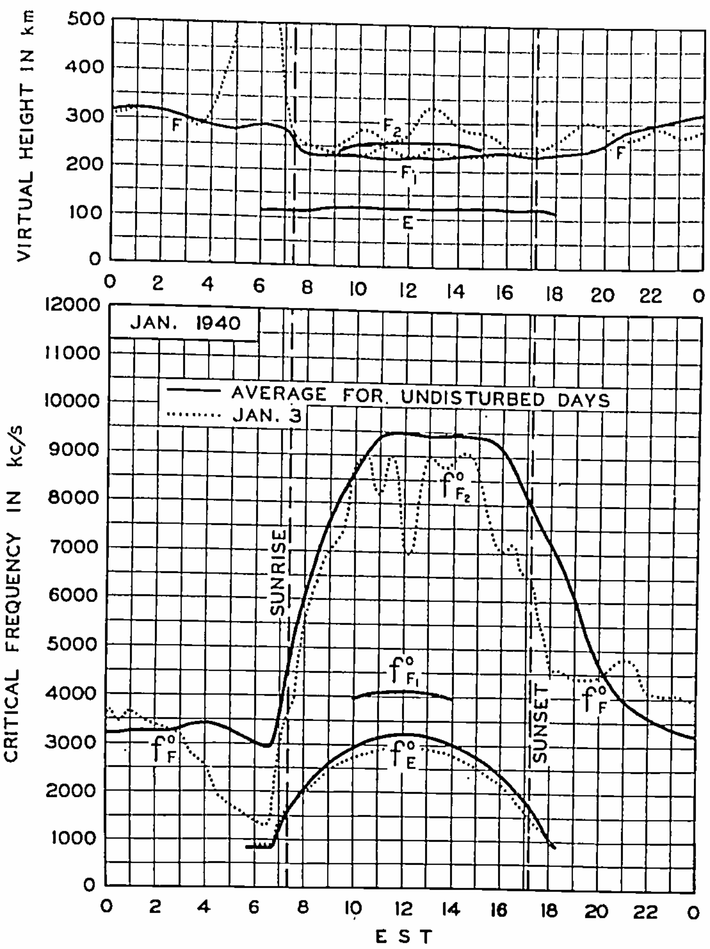


Fig. 1—Virtual heights and critical frequencies of the ionospheric layers, January, 1940. The solid-line graphs are the averages for the undisturbed days; the dotted-line graphs are for the ionospheric-storm day of January 3. The daytime f_E on January 3 were lower than on any other day of the month. This was partially due to the ionospheric storm and partially due to a trend of f_E.

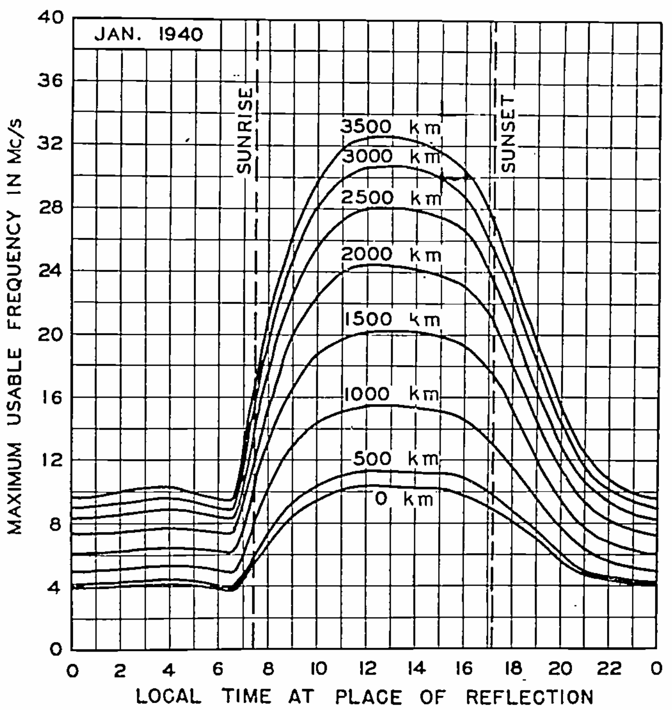


Fig. 2—Maximum usable frequencies for dependable radio transmission via the regular layers, average for undisturbed days for January, 1940.

layer absorption were observed for several hours during the middle of the day on January 4, 15, 16, 17, 21, 22, 23, and 24.

No strong vertical-incidence sporadic-E reflections were observed above 4.5 megacycles.

TABLE II
SUDDEN IONOSPHERE DISTURBANCES

Day	G.M.T. Beginning	G.M.T. End	Locations of transmitters	Relative intensity at minimum[1]	Nonradio phenomena
January 4	1859	1930	Ohio, Ontario	0.01	
6	1554	1630	Ohio, Ontario	0.0	
7	1608	1630	Ohio	0.1	
8	1805	1850	Ohio, Ontario	0.0	Terr. mag. pulse[2] 1805 to 1855 G.M.T.
12	1700	1740	Ohio	0.02	
20	1720	1800	Ohio	0.1	
25	1927	1940	Ohio	0.01	

[1] Ratio of received field intensity during fade-out to average field intensity before and after: for station WLWO, 6060 kilocycles, 650 kilometers distant.
[2] Terrestrial magnetic pulse as observed on Cheltenham magnetogram of United States Coast and Geodetic Survey.

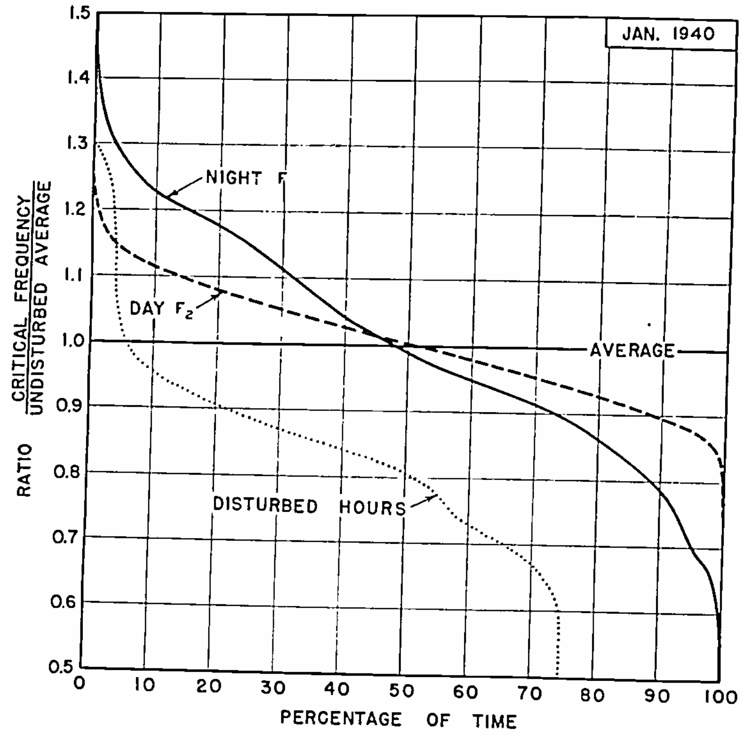


Fig. 3—Distribution of F- and F_2-layer ordinary-wave critical frequencies (and approximately of maximum usable frequencies) about monthly average. Abscissas show percentages of time for which the ratio of the critical frequency to the undisturbed average exceeded the values given by the ordinates. The solid-line graph is for 385 undisturbed night hours of observation; the dashed graph is for 210 undisturbed day hours of observation; the dotted graph is for 35 disturbed hours of observation, listed in Table I.

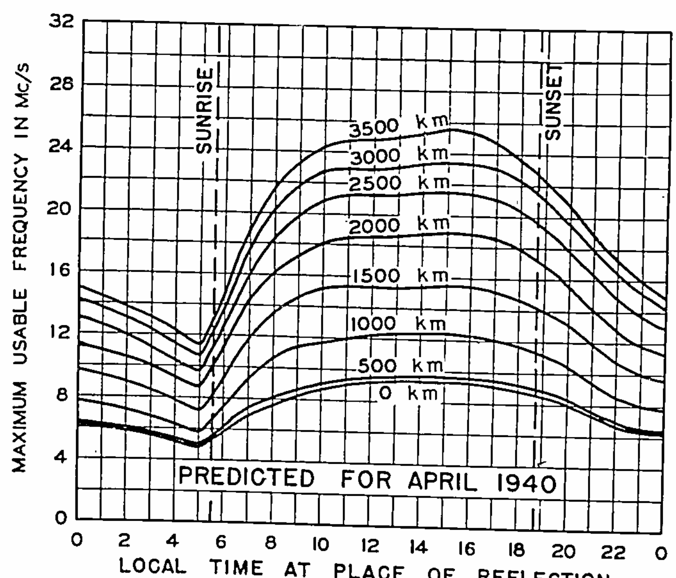


Fig. 4—Predicted maximum usable frequencies for dependable radio transmission via the regular layers, average for undisturbed days, for April, 1940.

JOINT MEETING WITH U.R.S.I.
April 26, 1940
Washington, D.C.

The annual joint meeting of the Institute and the American Section of the International Scientific Radio Union will be held in Washington, D.C., on Friday, April 26. This meeting will be held at the National Academy of Sciences, 2101 Constitution Avenue, from 10:00 A.M. to approximately 5:00 P.M., Eastern Standard Time. There will be no Saturday session. The papers will be presented in approximately the order listed below; the first eight are scheduled for the morning session. The afternoon meeting will start at 2:00 P.M. Correspondence should be addressed to S. S. Kirby, National Bureau of Standards, Washington, D.C.

PROGRAM

1. AURORAL OCCURRENCES AND IONOSPHERIC DISTURBANCES FROM FIELD-STRENGTH MEASUREMENTS, 1930–1940

HARLAN T. STETSON

(Massachusetts Institute of Technology, Cambridge, Mass.)

For the purpose of studying the effect of auroras on radio field intensity, a list of auroral observations made at the Blue Hill Observatory, Milton, Mass., was placed at the author's disposal through the courtesy of the Director, Dr. C. F. Brooks. The auroral intensities were observed on a scale of 0, 1, 2; 0 representing faint auroras, 1 those of intermediate brightness, and 2 very bright displays. The data in the list for the purpose in hand were restricted to occurrences of auroras of brightnesses 1 and 2. During the interval 1930 through 1939 thirty-eight displays meeting these conditions were recorded at Blue Hill. For thirty-two of these displays reliable field-strength data were available for the study of radio transmission conditions between Chicago and Boston on a frequency of 770 kilocycles.

Results of the investigation indicated that, beginning six days before the date of the aurora, field strengths were abnormally high with a maximum intensity occurring on the average four days before the date of the occurrence of the aurora. From three days before until two days after the auroral occurrence field strengths decreased to a minimum and remained abnormally low until about six days after. The average field strength for a typical year, 1938, was about 113 microvolts per meter. The average field strength four days before the auroral occurrence rose to 200 microvolts and the minimum record for one and a half days after the date of auroras averages 48 microvolts. The lag of one and one-half days from the night of auroral occurrence to the night of minimum field strength at broadcast frequencies suggests an accumulative ionization to the point of maximum interference with transmission through and from the E layer.

For higher frequencies involving the F layers an examination of the T.D. (transmission-disturbance) figures of the Bell Telephone Laboratories was made. For the thirty-eight bright auroral displays during the decade, a minimum of disturbance was noted four days before the occurrence. Transmission disturbance rose rapidly thereafter to a maximum one-half day following the dates of auroras. Transmission disturbances then subsided to near the average value six days after the dates of the auroras. The average T.D. minimum disturbance four days before was 2.1, whereas the maximum values recorded on the day of the aurora and the day immediately following averaged 3.8. A comparison of transmission conditions in the F and the E layers around auroral dates therefore leads one to the conclusion that the maximum disturbance not only follows auroral phenomena, but that the F layers are affected on the average about one day earlier than the E layer based on over three hundred days of observations utilized.

A similar comparison with the magnetic character figure *C* over the same interval showed a minimum value for *C* occurring four days before and a maximum value on the day of the aurora. This was followed by decreasing values until five days later.

A comparison of solar disturbances as marked by sunspot numbers over two sunspot periods, shows that on the average maximum solar activity occurs one day before the occurrence of auroral displays.

2. THE THREE-HOUR-RANGE INDEX, K: A NEW MEASURE OF GEOMAGNETIC ACTIVITY AS AN AID FOR COMMUNICATION SERVICES

J. Bartels
(Carnegie Institution of Washington),
N. H. Heck
(United States Coast and Geodetic Survey), and
H. F. Johnston
(Carnegie Institution of Washington), Washington, D. C.

The frequency and intensity of magnetic disturbance is supposed to indicate the influence of solar corpuscular radiation (of intensity P, say) on the earth's magnetic field. Various schemes for measuring the fluctuations of this geomagnetic activity are in operation, but studies on the ionosphere by radio methods and on radio transmission made a new scheme desirable. This is provided by the new three-hour-range index K as adopted by the International Association of Terrestrial Magnetism and Electricity at its Washington meeting, September 1939; K indexes are being broadcast daily and weekly. Each collaborating observatory assigns to each of the eight three-hour intervals of the Greenwich day one of the integers 0 to 9 as range index K, by a method which effectively separates the two main solar influences on the ionosphere, namely, P (supposedly due to *p*articles, and strongest in *p*olar regions) and W (supposedly due to *w*ave-radiation, restricted to the daylight hemisphere). It is described how P is measured by K, and a scheme for a geomagnetic record of W is sketched.

3. THE RELIABILITY OF PREDICTIONS OF IONOSPHERIC CHARACTERISTICS AND RADIO TRANSMISSION

J. H. Dellinger and N. Smith
(National Bureau of Standards, Washington, D. C.)

The hazardous task of forecasting monthly average values for ionospheric and radio conditions was undertaken by the National Bureau of Standards last year. Beginning in the March, 1939, issue of the Proceedings of the I.R.E., the Bureau has published each month, in addition to past observed values, predicted values for the month following that of publication. Because of the necessary lag in publication procedure, the predictions had to be made three months in advance.

There is now a set of published predictions as well as observed values, for each month throughout a full year. This paper presents and compares these published predictions and observations, and also presents some predictions of longer range for the future.

The monthly data were published in the form of graphs of maximum usable frequencies for dependable radio transmission via the regular layers, giving the monthly average values for undisturbed days, as a function of time of day and for various transmission distances. These graphs also predict critical frequencies and, implicitly, ionization densities of the F and F_2 layers (the number of electrons per cubic centimeter being 0.0124 times the square of the ordinary-wave critical frequency in kilocycles per second).

In announcing the prediction service the Bureau stated that predicted values were expected to have an accuracy within 15 per cent and the results show this to have been well met. The limit of accuracy is determined by the minor unpredictable variations of solar activity from its trend in the 11-year cycle.

4. SOME PHENOMENA IN THE F_2 REGION DURING GEOMAGNETIC DISTURBANCE

L. V. Berkner and S. L. Seaton
(Carnegie Institution of Washington, Washington, D. C.)

Associated with geomagnetic disturbances are well-defined changes in the F_2 region. For a particular storm the nature of these effects varies with latitude and season. These variations in character of the associated ionospheric effects for a large number of storms of different intensity are discussed. Unusual features of these changes during very intense storms are discussed.

5. IONOSPHERIC STUDIES DURING THE ANNULAR ECLIPSE OF APRIL 7, 1940

T. R. Gilliland and A. S. Taylor
(National Bureau of Standards, Washington, D. C.)

At the time this abstract is being prepared, in February, 1940, preparations are being made to conduct ionospheric measurements during the annular solar eclipse of April 7, 1940. These observations will be made both in southwestern Texas, which is in the path of the annular phase of the eclipse, and in Washington, where the eclipse is partial. It is expected that during the eclipse a decrease will occur in the ionization density of all the regular layers, i.e., and E, F_1, and F_2 layers. It is anticipated that the observations will yield valuable information regarding the recombination coefficient in, and the agency responsible for the ionization of, the various regions of the ionosphere.

6. THE PROPAGATION OF ELECTROMAGNETIC WAVES IN AN IONIZED MEDIUM AND THE CALCULATION OF THE TRUE HEIGHT OF REFLECTION OF THE IONOSPHERE

Olof E. H. Rydbeck
(Harvard University, Cambridge, Mass.)

It is shown that in certain cases the wave-mechanical interpretation of the propagation of electromagnetic waves in an ionized medium leads to a reasonably

simple picture of the propagation and reflection in the ionized regions.

When this simple interpretation is possible it is also possible to calculate the true height of reflection from the virtual-height-versus-frequency records. Thus the actual electron distribution can be obtained from the experimental data.

A few typical examples will be shown.

7. SOME MEASUREMENTS OF 540-KILOCYCLE PROPAGATION OVER THE HIGH-CONDUCTIVITY PRAIRIE PROVINCES

K. A. MacKinnon
(Canadian Broadcasting Corporation, Montreal, Canada)

Field measurements of the propagation of 540-kilocycle waves over the Prairie Provinces indicate ground conductivities approaching 1000×10^{-15} electromagnetic units with a maximum near south central Saskatchewan. Curves are presented showing actual measurements of signals from 200-watt and from 50,000-watt transmitters suggesting electrically uniform earth in certain directions to distances of the order of 400 miles. Comparison is made with propagation curves of different workers, especially in regard to the correction for a spherical earth.

8. DIRECTIONAL CHARACTERISTICS OF TROPICAL STORM STATIC

S. P. Sashoff and W. K. Roberts
(University of Florida, Gainesville, Fla.)

During the hurricane seasons of 1938 and 1939 recordings were made of the direction of arrival of static associated with tropical storms and particularly of static originating in tropical hurricanes. The method of obtaining the data has been described elsewhere.

This paper discusses the tabulated results for the above periods. It points out that static arriving at the three recording stations totalized over long periods of time seems to come from certain sharply defined sectors of the compass. It indicates that this directional distribution of static, for the summer months at least, may be associated with certain areas which appear to be very active in producing atmospherics. It shows that these areas in the Western Hemisphere may be located by triangulation.

The paper also discusses in detail records obtained on the tropical storm of August, 1939, which, although mild in intensity, was of considerable importance since its center passed only 100 miles from the recording station at Gainesville, Florida. The data on this storm indicate that: (a) only certain portions of the storm may be regarded as the principal sources of static; (b) the relative position of each area remains fairly fixed with respect to the storm center; and (c) as far as can be determined no static emanates from the eye of the storm.

9. FORCED-AIR VERSUS WATER-COOLING OF VACUUM TUBES

I. E. Mouromtseff
(Westinghouse Electric and Manufacturing Company, Bloomfield, N. J.)

Effectiveness of forced cooling by a moving fluid depends on physical constants of the fluid, its velocity, and dimensional parameters of the cooling device. Mathematical expressions connecting these factors are given, and variation of individual factors is discussed in respect both to water- and forced air-cooling. Mechanical and thermal limitations of air cooling devices are described, and limits of permissible anode dissipation discussed. Influence of the "cold ends" on dissipation limits is considered. General rules for designing an air-cooler are outlined.

10. SPACE-CHARGE RELATIONS IN TRIODES AND THE CHARACTERISTIC SURFACE OF LARGE VACUUM TUBES

E. L. Chaffee
(Harvard University, Cambridge, Mass.)

It is shown theoretically and experimentally that the plate, grid, and total currents, in the absence of secondary emission, vary as the 3/2 power of the plate voltage along lines of constant $L = e_{go}/e_{po}$, where e_{go} and e_{po} are measured from a displaced origin. The three currents are then expressed in the form $i = Ae_p^{3/2}(1+\mu L)^{3/2}F(L)$. The entire system of static curves for each current can be expressed by a single curve. A simplification in the experimental determination of the static curves is suggested, permitting the static curves to be plotted from a few measurements at low power. The effects of secondary emission are discussed and curves are given which aid in the design of tubes in which secondary emission from the plate is suppressed.

11. GRID INDUCTION NOISE IN VACUUM TUBES AT ULTRA-HIGH FREQUENCIES

Stuart Ballantine
(Ballantine Laboratories, Inc.. Boonton, N. J.)

When an electron or other charged particle passes through the meshes of the control grid it induces a varying charge thereon and if the external control-grid circuit contains impedance noise will be produced. This additional source of noise in vacuum tubes (which may be called *grid induction noise*) was pointed out in paper published in 1928 (*Jour. Frank. Inst.*, August, 1928) and the present paper is a quantitative elaboration of the theory of the effect. Assuming no net conduction current to the control grid, the induction noise vanishes at low frequencies and increases with frequency, reaching a maximum at a frequency commensurate with the transit time. Additional maxima and minima appear with further increase in frequency, Calculations of the noise produced under both temperature-limited and space-charge conditions will be given. Both the grid-cathode and plate-grid transit times are involved. With modern tubes the noise due to electrons will begin to assume importance at frequencies of the order of 100 megacycles and above, while that due to ions will appear at frequencies which are lower in proportion to the higher ionic masses. As in the case of the noise due to shot effect the presence of space-charge effects a reduction over the temperature-limited condition. Curves will be shown for the spectral distribution of energy in the grid induction noise under typical practical operating conditions.

12. A NEW METHOD FOR THE DETERMINATION OF THE AXES OF QUARTZ CRYSTALS BY MEANS OF ETCH FIGURES

W. G. Cady
(Wesleyan University, Middletown, Conn.)

In his book entitled "Recherches sur le Quartz Piézoélectrique" (Paris, 1935), A. de Gramont shows that when a beam of light is passed through a quartz-crystal slab, one face of which has been etched with hydrofluoric acid, the rays are refracted in different directions, so that a lens placed close to the crystal projects onto a screen an image that is characteristic of the particular face that has been etched. If the etched surface is normal to the optic axis (z axis), the pattern takes the form of a three-pointed star, the points indicating the direction of the x axis with a precision of about a degree.

In repeating Gramont's experiment the writer found that the pattern can be viewed directly through a powerful lens, for example a $\frac{1}{4}$-inch microscope objective. The observed image is not the magnified view of a single etch figure, but rather a synthetic picture integrated out of a very great number of individual etch figures. It is not necessary to polish the crystal surface before etching. This method furnishes for the first time a simple and accurate optical method for finding the direction of the electric axes on a z-cut slab of quartz.

13. THE USE OF AN ETCHED SPHERE OF QUARTZ IN IDENTIFYING THE ORIENTATION OF QUARTZ PLATES

Karl S. Van Dyke
(Wesleyan University, Middletown, Conn.)

There are a number of papers in the literature dealing with the etch patterns which appear on quartz when it is etched with hydrofluoric acid and on the etching of quartz spheres. Among these there are a few discrepancies and contradictions particularly as they relate to the distinction between left and right quartz, as there is also similar confusion in the literature which deals with the temperature coefficient of various "cuts" of quartz resonators. With resonators, confusion as to the right- or left-handedness of the quartz is particularly serious because it is the variation of the elastic properties of the quartz with orientation upon which depend the special properties which are sought.

The present paper aims to rectify the discrepancies. The terminology and conventions of the physicist, the chemist, the mathematician, the mineralogist and the radio engineer have all been considered in questions of right and left quartz, right and left optical rotation, right-handed and left-handed sets of axes, signs of angles, and the experimental facts on wave velocities in various directions.

Also the orientation of a number of resonators is proved by comparison of (1) the markings on their etched surfaces with those on an etched sphere, and (2) their frequencies and dimensions with the curves for the elastic properties of quartz; also by tests of the optical rotation of the quartz, and the electrical polarization under mechanical pressure as well as surface charges developed during cooling. (Kundt's red-lead and sulphur test.)

All of the factors concerned, etch figures, optical rotation, electrical polarization, and resonant frequencies, are in entire agreement with the elastic constants given by Voigt, and his equations for rotating the axes of reference, when used with his conventions as to axes and signs of angles. Taken together they also make it possible to determine the peculiar and sometimes unstated conventions used by others in their published data.

14. A NOTE ON THE DIURNAL VARIATION OF ULTRA-SHORT-WAVE "OPTICAL" -PATH TRANSMISSION

C. R. Englund, A. B. Crawford, and W. W. Mumford
(Bell Telephone Laboratories, Holmdel, N. J.)

Continuous records of ultra-short-wave transmission on wavelengths of two and four meters, over a good "optical" path, have shown variations in the received signal strength. These variations can be explained as being caused by wave interference, an interference which varies with the changes in the composition of the troposphere. The diurnal meteorological factors which affect the transmission are discussed.

15. AN ULTRA-HIGH-FREQUENCY VOLTMETER

Andrew Alford
(Mackay Radio and Telegraph Co., New York, N. Y.)
and
Sidney Pickles
(International Telephone Development Co., New York, N. Y.)

At high frequencies reasonably accurate current measurements can be made so that such things as transmission-line currents can be measured to determine transmitted power from an accurately calculated surge impedance. At ultra-high frequencies no such meters can be used on a line because of the line and meter dimensions. However, at ultra-high frequencies the same type of current-indicating instruments when associated with closed quarter wavelengths of line can be readily turned into accurate voltage-indicating devices which hold calibrations within the limits of engineering accuracy over large ranges of the ultra-high-frequency spectrum. Since surge impedances of lines at these frequencies can still be accurately calculated, voltages instead of currents can be used to measure transmitted power.

16. FIELD STRENGTH OF MOTORCAR IGNITION BETWEEN 40 AND 450 MEGACYCLES

R. W. GEORGE
(R.C.A. Communications, Inc., Riverhead, L. I., N. Y.)

Measurements of motorcar-ignition peak field strength were made on frequencies of 40, 60, 100, 140, 180, 240, and 450 megacycles. Propagation was over Long Island ground and the receiving antennas were 35 feet high and 100 feet from the road. Under these conditions, the average field strength varied about 2 to 1 over the frequency range. Curves show the maximum field strength versus frequency for 90, 50, and 10 per cent of all the measurements. Vertical and horizontal polarization are compared showing slightly greater field strength in general for vertical polarization. New cars, old cars, and trucks are compared showing no large differences of ignition field strength.

Some of the factors involved in motorcar-ignition radiation are mentioned. Theoretical propagation curves are included and the measuring system is briefly discussed.

17. CURRENTS INDUCED IN WIRES BY HIGH-FREQUENCY ELECTROMAGNETIC FIELDS

ANDREW ALFORD
(Mackay Radio and Telegraph Co., New York, N. Y.)

This paper deals with the nature of currents which are induced in wires of various lengths by uniform and nonuniform electromagnetic fields. The experiments and theory which are discussed show that, except in the special cases when resonance phenomena predominate, the induced currents are not even approximately sinusoidally distributed and that, therefore, theories based on the *a priori* assumed sinusoidal distributions are limited to wires of certain special resonant lengths.

The special cases considered include a wire placed at right angles to the direction of propagation of an electromagnetic wave arriving from a distant source, a wire placed at an angle to the direction of propagation, and a wire placed parallel to a half-wave transmitting antenna at a small distance from it so that the inducing field is not uniform.

Submission of Papers

Fifteenth Annual Convention

The papers program for the Fifteenth Annual Convention, to be held in Boston, Massachusetts, on June 27, 28, and 29, 1940, is now being prepared. Anyone wishing to submit a paper for presentation should forward it to the Institute office not later than May 1, 1940. The paper must be accompanied by a brief summary for inclusion in the Convention program to be published in the June PROCEEDINGS. A statement should also be made as to the approximate time that will be required for presentation.

Sections

Atlanta

I. H. Gerks, professor of electrical engineering at Georgia School of Technology, presented a paper on "Fundamentals of Frequency Modulation."

After outlining the history of the field, the fundamentals were considered. Mathematically, the existence of a carrier and sidebands in an amplitude-modulated wave was demonstrated and the same concept was then covered by the use of vectors. Both phase and frequency modulation were similarly treated and the differences pointed out.

The Armstrong system of developing phase modulation into frequency modulation was described as was another method which does not require the use of a large number of frequency multipliers. Various methods of detecting these waves were described.

The advantages and disadvantages of this system of modulation were outlined.

November 17, 1939, Ben Akerman, chairman, presiding.

This was the annual meeting of the section and in the election of officers P. C. Bangs was named chairman, G. S. Turner was elected vice chairman, and Adolph Andersen was designated secretary-treasurer.

A paper on "Frequency Modulation" was presented by J. H. DeWitt, chief engineer of WSM.

Data were given on the relative band widths and power distribution for amplitude- and frequency-modulated waves. The effect of noise on reception was discussed. Although the band width required for frequency-modulated waves was greater than for amplitude-modulated waves, some compensation results when the required signal-to-noise ratio necessary for satisfactory reception is considered.

A transmitter and a receiver were demonstrated at the close of the paper. The transmitter was located in a neighboring hotel and the receiver was in the meeting room. The effect of noise was demonstrated by shifting from amplitude to frequency modulation.

By transmitting a pure tone with frequency modulation and using a cathode-ray tube on the receiver, the effect of detuning the receiver was demonstrated. Correct tuning exists when noise is at a minimum and detuning causes serious distortion. The demonstration was concluded by playing a record made at Nashville in August, 1939, of a 42.8-megacycle transmission from the Armstrong station located in New York.

January 19, 1940, P. C. Bangs, chairman, presiding.

Baltimore

A paper on "Design of Radio Receiving Equipment to Meet Special Requirements" was presented by W. L. Webb, engineer in charge of the receiver and radio-compass engineering department of the Bendix Radio Corporation.

Receivers for special purposes may differ considerably from those used in broadcasting. The design of such receivers requires a careful observance of the specifications which they must meet. If the specifications are thorough, the entire design can be based on them. Whereas, if the specifications are incomplete, the designer must estimate from the data available what the remaining performance and design features shall be.

With the specifications known, the

engineer may proceed with the circuit design deciding on the general type, number of stages, and number of bands required. The stage gains and number of stages are worked out by starting at the output stage and proceeding toward the input stage. Several examples were given of calculating the requirements to give a desired image-frequency rejection.

The mechanical design must consider several factors as size, weight, type of tuning, and band switching. Finally, the design must be prepared to permit economical manufacture. The last step is considered as being the most difficult.

Several radio-compass receivers were displayed as examples of compact mechanical design which also permits rapid servicing.

January 19, 1940, C. A. Ellert, chairman, presiding.

H. S. Black of Bell Telephone Laboratories, presented a paper on "Feedback as Applied to Amplifiers."

Some of the earlier forms of feedback amplifiers were discussed and it was pointed out that the balanced type, while giving good results, demanded accurate adjustment and components built to close tolerances.

The general theory of the feedback amplifier was then outlined. It was pointed out that reintroducing, out of phase, a portion of the amplifier output into the input circuit not only cancels most of the distortion produced by the amplifier but increases the stability of amplification and the linearity with gain which becomes independent of input and the load capacity. It also reduces modulation effects, noise, and the susceptibility of the circuit to external fields. The feedback circuit provides a convenient place for equalization and gain control. Both phase shift and phase distortion are lowered and either constant current or constant voltage can be delivered to loads of varying impedance. The impedance values are stabilized. Components with large tolerances may be used. A feedback amplifier receiving its input from a phonograph record and supplying power to a loud speaker and cathode-ray oscilloscope was demonstrated. The author was assisted by E. K. Van Tassel and J. B. Maggio of Bell Telephone Laboratories.

February 16, 1940, C. A. Ellert, chairman, presiding.

Boston

A symposium of "The CAA-MIT Instrument Landing Research" was presented by a group from the Massachusetts Institute of Technology.

The subject was introduced by E. L. Bowles who described the research program which has been in operation for several years under the sponsorship of the Civil Aeronautics Authority. The significant results obtained were indicated and the other speakers were introduced to describe their activities.

W. M. Hall demonstrated the three-spot cathode-ray oscillograph on the screen of which appear spots representing the three landing lights arranged in a triangular position which would be seen in times of good visibility. Modifications of the pattern and the application of the instrument to en route flying were described.

C. S. Draper described the special gyroscope used for obtaining a necessary electrical output. The problem of obtaining this output while still maintaining the accuracy of the gyro to a fraction of a degree was outlined.

W. L. Barrow discussed the type of radio signals used. Pipe-type antennas were used to produce very straight crossed beams. Horizontal polarization gave less variation in reflection than did vertical. The marker beacons employ single and double beams modulated at 90 and 150 cycles and give beams 200 to 400 feet wide at distances up to 10 miles.

D. E. Kerr described the transmitting equipment. One transmitter utilizes a standpipe-type of oscillator having coaxial lines in the grid and filament leads. Supply-voltage stabilization is necessary for frequency stability. The output is about 1 watt. A Klystron used for higher powers gives about 50 watts output. Mechanical controls of a coaxial-type used to vary modulation, volume, and wave form were described.

F. D. Lewis discussed the various receivers used. For measuring beam characteristics a receiver using a grid-leak triode detector is mounted on a bamboo kite. Other receivers use diodes giving more nearly linear response and coaxial-line tuners. The features of an unorthodox superheterodyne using a very stable ultra-high-frequency oscillator were outlined.

Professor Bowles closed the symposium by a discussion of tests which indicate that 50-watt transmitters would be useful to distances beyond 25 miles and that a reliable straight-line glide path of 5 miles is easily obtained.

October 27, 1939, W. L. Barrow, chairman, presiding.

C. A. Clarke, commercial engineer for the International Telephone Development Company, presented a paper on "Selenium Rectifiers."

It covered the use of metallic selenium dry-plate rectifiers for power purposes at frequencies up to 1000 cycles.

These rectifiers were stated to have a wide permissible temperature range of operation, small size and weight for a given output, stability, long life, permissible overloads, and high efficiency over a broad variation in load. They may be used for high-current low-voltage applications such as electroplating, or for high-voltage low-current purposes such as vacuum-tube plate supply. High efficiency results from a low forward resistance and small reverse current. The resistance has a negative temperature coefficient which helps cancel the positive characteristics of the copper used elsewhere in the circuit.

Some uses of the rectifiers which were described were as voltage doublers for cable testing giving inherent protection against short circuits, frequency doubling for telephone dialing and busy tones and for an electric hammer, counterelectrolysis, as an energy absorber in a spark quencher, and as a telephonic acoustic-shock protector.

November 24, 1939, W. L. Barrow, chairman, presiding.

Two papers on twin-T null circuits were presented by engineers of the General Radio Company.

The first on "General Properties of Bridged-T and Parallel-T Null Circuits and a Simple Method of Determining Balanced Conditions," by W. N. Tuttle, contains essentially the material presented in a paper by the same author and of a similar title which appeared in the January PROCEEDINGS.

D. B. Sinclair presented the second paper which was on "The Design of an Instrument Using a Parallel-T Null Circuit for Measuring Impedances in the Range from 0.5 to 30 Megacycles."

The developmental problems met in the design of such an instrument and a number of its interesting features were described. Circuit diagrams, equations for balance, and methods of calculating the results to be expected were given. An indication of the order of magnitude of the accuracy of the measurements was provided.

December 15, 1939, W. L. Barrow, chairman, presiding.

A paper on "Square Waves" was presented by L. B. Arguimbau, research associate at Massachusetts Institute of Technology. He reviewed first various ways of estimating the response of networks to speech and music, comparing steady-state and transient methods.

Response curves of simple networks, when subjected to square waves, were derived and discussed in relation to responses found experimentally for complicated systems such as amplitude-modulated-wave and frequency-modulated-wave broadcasting.

A demonstration was given showing the response curves of a wide variety of circuits including a radio receiver, a phonograph recorder and reproducer, a loud speaker, a transformer, and an amplifier. It was observed that a loud speaker gave a much poorer response than did an electrical system including two frequency-modulated-wave transmitters and receivers. The acoustic link, being the poorest part of the system, offers greatest opportunity for improvement.

At the close of the paper, there was a considerable discussion of acoustic problems which included the applicability of Ohm's acoustic law to speech. It was apparent that the square-wave method while satisfactory for electrical systems is too sensitive for testing acoustic and electromechanical systems. In these cases, however, it should prove suggestive and helpful in a qualitative way.

January 26, 1940, W. L. Barrow, chairman, presiding.

Buenos Aires

A paper on "Microphones" was presented by Adolfo Di Marco, associate professor at La Plata University.

The principles and operation of various types of microphones were first presented. The equivalent electrical circuits of various types were given and methods used to equalize their response as a function of frequency were outlined. The sensitivity and directional characteristics were discussed and a simplified method for direct comparison with standards of pressure which have been universally adopted was considered.

Present studio practice in the choice of microphones and their utilization for various types of programs under various acoustic environments were covered.

The meeting was closed with a demonstration on the measurement of the height of the ionosphere which was presented by L. M. Malvarez, associate professor at La Plata University, and a visit to the Astronomical Observatory of the University.

October 14, 1939, E. E. Kapus, secretary, presiding.

Buffalo-Niagara

J. R. Nelson of the Raytheon Production Corporation, presented a paper on "Noise in Vacuum Tubes and Associated Circuits."

The behavior of a vacuum tube was discussed with emphasis on those factors which contribute noise. A mathematical presentation of the physical conditions involved included treatment of thermal agitation and shot effect. The noise characteristics of several modern tubes were shown by curves.

This was the annual meeting and K. B. Hoffman, chief engineer of the Buffalo Broadcasting Company, was elected chairman; B. E. Atwood, an engineer for the Colonial Radio Corporation, was designated vice chairman; and E. C. Waud was re-elected secretary-treasurer.

January 17, 1940, H. C. Tittle, chairman, presiding.

A paper on "Rectifiers" was given by E. M. Sabbagh, professor of electrical engineering at Purdue University. The theory of the operation of both gaseous and vacuum-tube rectifiers was outlined. Rectification characteristics of various devices were presented in both mathematical and graphical form.

February 14, 1940, K. B. Hoffman, chairman, presiding.

Chicago

A symposium on loop antennas, comprised of three papers, was presented.

W. E. Cairnes, assistant chief engineer of the Galvin Manufacturing Company, discussed the "Application of Loop Antennas to Broadcast Receivers." The second speaker, W. O. Swinyard, an engineer for the Hazeltine Service Corporation, presented a paper on "Loop-Antenna Receiver Measurements." The concluding speaker, George Levy, an engineer for United Airlines Communication Laboratory, discussed the use of "Loop Antennas for Aircraft."

This was the annual meeting of the section and E. H. Kohler of the Ken-Rad Tube and Lamp Corporation, was elected chairman; G. I. Martin, RCA Institutes, Inc., was named vice chairman; and P. C. Sandretto of United Airlines Transport Corporation, was designated secretary-treasurer.

December 1, 1939, V. J. Andrew, chairman, presiding.

"Development in Radio Aids to Avigation" was the subject of a paper by P. C. Sandretto, superintendent of the communications laboratory of the United Airlines Transport Corporation.

Early attempts to guide aircraft by the use of radio were first described. Difficulties caused by interference were outlined and the solutions indicated.

The first use of radio-compass equipment was described and the early types of radio-beam transmitting equipment were covered. Antenna developments were then considered as was transmitting equipment. Both oral and visual-indicator types of receiving equipment were described. The pecularities of precipitation static and the research that resulted in a method of greatly reducing the interference it causes to radio reception on a plane in flight were discussed. The paper was concluded with a brief treatment of automatic landing mechanisms and instrument landing methods.

January 26, 1940. E. H. Kohler, chairman, presiding.

Cincinnati

"The Vocoder Remakes Speech" was the subject of a demonstration lecture by Homer Dudley of Bell Telephone Laboratories before a joint meeting with several other societies.

The Vocoder led to the development of the Voder which was demonstrated at the New York and San Francisco Fairs in 1939.

The sound-producing organs of the human body consist of three parts: the power supply or lungs, the vocal cords which produce a buzz or hiss, either singly or in combination, and the tongue, lips, and teeth which form these sounds into intelligible speech.

Any electrical system of similar properties consists of a power supply, an instrument to produce buzzes and hisses, and a network to combine these so as to form intelligible speech. This network might be called a quality control. The Vocoder, which is comprised of these mechanisms, was then demonstrated.

January 11, 1940, G. W. Little, chairman, American Institute of Electrical Engineers, Student Branch, University of Cincinnati, presiding.

At the fifth annual joint meeting of all technical societies in Cincinnati, a paper on the "200-Inch Reflector Telescope Disk" was presented by O. A. Gage, physicist for the Corning Glass Company. A broad picture of the general design and constructional problems in the casting of these large pieces of glass was presented and the meeting was concluded with the showing of some motion pictures of the pouring and annealing operations as well as the grinding and polishing work done at Mount Palomar.

February 21, 1940, W. W. Parks, president, executive committee of Cincinnati Council Societies, presiding.

Cleveland

The paper on "Basic Economic Trends in the Radio Industry" by Julius Weinberger of the license division of the Radio Corporation of America, which was published in the November, 1939, PROCEEDINGS, was presented.

October 28, 1939, S. E. Leonard, Chairman, presiding.

F. A. Lennberg, sales engineer for the Bliley Electric Company, presented a paper on "Quartz Crystals."

The piezoelectric effect was described and the characteristics of several substances presenting this phenomenon were touched on. The qualities of quartz obtained from various parts of the world were compared.

The crystal structure of quartz was described and methods of determining the axes by examination of growth lines with polarized light were explained. Complications in the crystal structure, such as twinning, were noted.

The reasons for crystals resonating at more than one frequency were described and methods of making a single-frequency oscillation predominate were illustrated. Methods of reducing the variation of frequency with temperature were described and their effects indicated graphically. The equivalent electrical circuits of crystals were outlined.

Methods of mounting crystals were described and their application to various oscillator circuits was covered. The danger of excessive feedback rupturing the crystal was pointed out. Various applications of crystals other than to radio were touched upon and included the measurement of pressures in firearms and motors and in supersonic-wave work. A number of crystals were on display. At the close of the meeting, a short motion picture on television was shown.

November 20, 1939, S. E. Leonard, chairman, presiding.

"The Microphone and Research" was the subject of a paper by F. S. Goucher, physicist of the Bell Telephone Laboratories, presented before a joint meeting with the local section of the American Institute of Electrical Engineers.

The history of the development of early types of microphones other than carbon was presented. The development of the carbon microphone was then considered. There were treated also the results of research into the fundamental mechanism of microphone action.

Models of all the microphones described were demonstrated by means of magnetic-tape recording which permitted immediate playback for comparison with the original.

The technique developed for measuring the extremely small displacements encountered in microphones was described and the mathematical attack on the solution of the resistance change resulting from displacement was demonstrated.

December 14, 1939, H. J. Dible, chairman, Cleveland Section of the American Institute of Electrical Engineers, presiding.

This was the annual meeting of the section and no formal paper was presented. A series of motion pictures were projected and dealt with the construction of vacuum tubes, the laying of submarine cables, transatlantic radiotelephone equipment, and similar subjects.

In the election of officers, R. L. Kline of Winteradio, Inc., became chairman; C. E. Smith, assistant chief engineer of the Radio Air Service, was elected vice chairman; and J. D. Woodward of WGAR, was designated secretary-treasurer.

The meeting was closed with a travelogue through five national parks presented by E. L. Gove, a former chairman of the section, and his wife.

December 28, 1939, S. E. Leonard, chairman, presiding.

Connecticut Valley

"The New Frequency-Modulated Transmitter of WDRC-W1XPW" was described by K. A. McLeod, development engineer for the station.

The physical setting of the station on the south peak of Meriden Mountain was first described. The power and telephone lines are brought in over an 800-foot precipice.

The various transmitter elements were described and the use of dual coaxial lines to obtain a very high degree of shielding was covered. Transmission from the station was demonstrated and compared with direct switching to the same program as received over a telephone line of the type used for broadcasting.

At the close of the paper a number of those present made an inspection trip to the station.

In the annual election of officers, R. N. Ferry of the Travelers Broadcasting Service, was named chairman; K. A. McLeod of WDRC-W1XPW, became vice chairman; and W. M. Smith was elected secretary-treasurer.

January 25, 1940, E. R. Sanders, chairman, presiding.

Detroit

A. B. Buchanan, radio engineer for the Detroit Edison Company, discussed the "Special Emergency Radio Communication System" used by that company. A 150-watt transmitter operating at about 40 megacycles energizes a closed-J antenna which is mounted on a steel tower about 230 feet high. The urban area to be covered is about 12 miles in radius and is quite flat. A field-strength and noise-level survey now being made has already disclosed data on which modifications of the system will be based.

The transmitter is remotely controlled by means of telephone circuits from an office building about six miles away. The transmitter is operated by dispatchers with any necessary adjustments or repairs being made by licensed operators.

Receivers average about one failure per year.

October 20, 1939, H. D. Seielstad, chairman, presiding.

A. F. Van Dyck, manager of the RCA License Laboratory, conducted a lecture and demonstration of RCA television equipment.

The development of television was first outlined. A general description of the present system was given and the meeting closed with a demonstration. A studio was set up in the lobby of the auditorium and students from the University of Michigan supplied the talent. The television signals were transmitted by wire to six receivers located in the auditorium. The program was repeated several times in order that all might have an opportunity of viewing the pictures from a suitable position and after each demonstration the viewers went into the lobby to witness the staging of the next program.

The meeting was held jointly with the College of Engineering of the University of Michigan.

November 3, 1939.

F. A. Firestone, professor of physics at the University of Michigan, demonstrated some recent developments in acoustics.

He treated first the advantages of the mobility method of computing the vibration of linear, mechanical, and acoustic systems.

A demonstration of public speaking in which the vocal cords of the speaker were not used was then given. The output of a loud speaker driven by a relaxation oscillator was introduced into the mouth of the speaker by a tube. Manual controls on the oscillator for pitch and volume assist in synthesizing speech.

By replacing the relaxation oscillator with an electric organ the demonstrator could sing without the use of his vocal cords. Professor Firestone "sang" not only solos but duets and quartets and demonstrated a wide variety of sound effects.

This was the annual meeting of the section and J. D. Kraus of the University of Michigan, was named chairman; R. J. Schaefer of the Briggs Manufacturing Company, was named vice chairman; and Paul Frincke, chief engineer of WJBK, was elected secretary-treasurer.

December 15, 1939, A. B. Buchanan, acting chairman, presiding.

"Design Features of Electrical Indicating Instruments" were discussed by T. S. Cawthorne, engineering sales representative of the Weston Electrical Instrument Corporation.

The development over the past fifty years of the permanent-magnet moving-coil-type instrument was first outlined. The discussion then covered rectifier and thermocouple instruments.

The rectifier-type instrument, though not ideal, offers a practical means of measuring very low values of alternating current. Its accuracy depends on the circuit, frequency, wave shape, and temperature. Operated at room temperature at a frequency below 10,000 cycles and with a current of approximately sine-wave form, its accuracy would be within 3 per cent.

The paper was closed with a discussion of several types of thermocouples.

January 19, 1940, J. D. Kraus, chairman, presiding.

Emporium

President Horle acted as guest chairman and spoke briefly of the latest changes in the Institute Constitution. He discussed also the relation of college students to the Institute. The speaker of the evening, H. C. Knutson, professor at Lehigh University, was introduced by President Horle and spoke on "Facsimile."

He pointed out that facsimile is slow-speed television limited to the transmission of stationary images. The picture quality must be higher than for equivalent television quality as the latter supplies but fleeting images.

The two facsimile systems now used in broadcasting were described and their differences in construction and operation pointed out. Both receivers use white paper on which the recording is done through carbon paper. It was the opinion of the speaker that a photographic process would be superior.

At the present time, home facsimile receivers are considered as requiring adjustments of such delicacy as to make their effectiveness questionable. It was pointed out that facsimile cannot supplant newspapers at the present speed of transmission; about three and one-half days would be required to transmit an average newspaper.

Three main problems which require further work were listed as synchronization of the transmitter and the receiver, the elimination of the effects of signal fading, and photographic recording at the receiver.

Both the Finch and the Radio Corporation of America equipment were demonstrated at the close of the paper.

February 1, 1940, C. R. Smith, chairman, presiding.

"RCA Television Demonstration Unit" was the subject covered by two engineers of the RCA Manufacturing Company.

W. C. Turner described technically the television equipment which was installed as part of the RCA exhibit at the Golden Gate International Exposition last summer.

Irving Steinberger then discussed the problems involved in the installation of television receivers placing special emphasis on the antenna. At the close of the paper, television transmitting and receiving equipment was available for inspection.

November 28, 1939, F. G. Albin, chairman, presiding.

A paper on "Facsimile Transmission" was presented by M. D. McFarlane of the M. D. McFarlane Laboratories.

In presenting an historical outline of the developments of facsimile, it was pointed out that some of the early systems incorporated all of the ideas used at present. New techniques have resulted in refinements.

Most systems may use radio or wire circuits for transmission. The time required for transmission is related to the amount of detail desired in the finished picture.

A technical description was presented of equipment which is reasonably portable, simple in operation, and can be connected to any telephone line. A 7-by-9-inch picture can be transmitted in about 8 or 9 minutes.

Prints of a number of transmitted pictures were used to illustrate the effects of improper adjustment of equipment or unsatisfactory transmission characteristics. The most recent pictures are so perfect as to leave the average person unaware of the fact that they have been transmitted over a facsimile system.

In the election of officers, A. C. Packard of the Columbia Broadcasting System, was elected chairman; M. T. Smith of the General Radio Company, was named vice chairman; and J. N. A. Hawkins of the Walt Disney Studios, was elected secretary-treasurer.

December 28, 1939, F. G. Albin, chairman, presiding.

Philadelphia

"Recent Advances in Engineering Electronics" were discussed by D. G. Fink, managing editor of *Electronics*, at a joint meeting with the local section of the American Institute of Electrical Engineers.

Defining electronics as covering electrons in motion generally through gases or space, the author outlined recent advances in the field. The Novachord electrical-musical instrument with its 163 tubes was described. The principles of the Voder for producing synthetic speech were outlined.

Many applications of light-controlled phototube apparatus were described and included the counting of parts, inspection of cloth, preventing accidents, control of railway signaling, and the control of lighting of factories and schools.

Other advances described included the electronic microscope giving magnification to about 50,000 diameters which has revealed details not before known, the electroencephalograph which will detect minute electric currents generated by the brain, and the miniature radio transmitters used in meteorological studies.

The paper was closed with a description of advances made in generating ultra-high frequencies by the Klystron and the utilization of waves of this type for indicating the height of an airplane above the earth.

January 8, 1940, R. S. Hayes, chairman, presiding.

At a joint meeting with the Franklin Institute, Robert Dawson of the United Airlines Transport Corporation, presented a paper on "The Radio Operation of a Modern Airliner."

Captain Dawson described how radio-range beacons and communication equipment assist the aviator in his work. Before starting a trip, the pilot is supplied with complete weather information furnished by the government and the weather service of the line. He charts with the weather official a forecast of anticipated conditions and must receive approval of his chart before taking off. Additional weather information is supplied during flight and he reports on conditions encountered. Icing conditions and static offer greatest danger. The static trouble has been substantially eliminated by trailing a discharge wire from the tail of the plane. These wires break off sometimes in flight and extra ones are carried and may be released by the pilot at will.

February 7, 1940, R. S. Hayes, chairman, presiding.

Pittsburgh

R. D. Wyckoff, a geophysicist for the Gulf Research and Development Company, presented a paper on "Modern Geophysical Explorations."

Various methods of locating the presence of minerals and oil were described. Measurements of the force of gravity and seismographic prospecting were outlined. Exploration on land, water, and in swamps was described. A number of pieces of equipment used in this type of work were exhibited.

January 16, 1940, Gary Muffly, secretary-treasurer, presiding.

Portland

A paper on "An Electronic Nerve-Impulse Analyzer" was presented by F. A. Everest, W. H. Huggins, and R. S. Dow. The first two authors are in the electrical engineering department of the University of Oregon and Dr. Dow is assistant professor of anatomy at the Medical School of that university.

This was the annual meeting and Marcus O'Day, professor of physics at Reed College, was elected chairman: E. R. Meissner of the United Radio Supply, Inc., was named vice chairman; and Earl Schoenfeld of the U. S. Forest Service Radio Laboratory, was elected secretary-treasurer.

January 10, 1940, H. C. Singleton, chairman, presiding.

San Francisco

"Thyratron and Gas Tubes—Their Application and Construction" was the subject of a paper by David Packard of the Packard-Hewlett Company.

The characteristics of thyratrons and ignitrons were covered and various manufacturing techniques and mechanical constructions were outlined. The paper was closed with a discussion of the industrial applications of these tubes for resistance welding and the obtaining of direct current for industrial use and high-voltage transmission.

In the election of officers, Carl Penther of the Shell Development Company, became chairman; Leonard Black, professor of electrical engineering at the University of California, was named vice chairman; and H. E. Held, manufacturers representative, was designated secretary-treasurer.

December 20, 1939, F. E. Terman, chairman, presiding.

"Some Problems in the Design of Aircraft Accessories" were discussed by R. M. Heintz.

Power requirements on aircraft have grown from simple direct-current sources to both direct- and alternating-current supplies of various types. Many factors affect the choice of supplies and both single and polyphase systems having frequencies as high as 800 cycles are being used. The present trend apparently is back to direct current with voltages of about 48.

A major problem is the method of obtaining the energy. In some cases hydraulic or mechanical coupling is made to the main engine. The possibility of utilizing the energy wasted in engine heat has been considered.

Frequency modulation apparently offers definite advantages and is receiving considerable attention as is the terrain-clearance altimeter and the Klystron as a generator of ultra-high-frequency waves.

January 17, 1940, Carl Penther, chairman, presiding.

"Engineering and Operation of Modern Broadcast Stations" were discussed by R. V. Howard, chief engineer of KSFO.

The administrative organization required for a broadcast station was first considered. The transmitter was then considered and the effect of various locations in the San Francisco area were discussed. The advantages of directive antennas were pointed out.

In considering studios, both measured and calculated values were given of their acoustic properties. It was shown that drapes, although causing a faster rate of decay of sound waves, do not appreciably affect the over-all time of decay. Their effects are greater as the frequency is increased. A method of varying studio acoustics by means of rotating baffles of varying sound-absorbing qualities was discussed.

February 14, 1940, Carl Penther, chairman, presiding.

Seattle

O. C. Smith and N. L. Bingham, engineers for the Pacific Telephone and Telegraph Company, discussed the subject of "Amplifiers for Use with Program Supply Circuits."

Mr. Smith outlined the need for amplifiers and equalizers in the transmission of broadcast programs. Impairment of fidelity caused by phase distortion was described and corrective methods presented.

Mr. Bingham discussed the routing of programs into Seattle and methods and equipment used in handling the programs between the line terminals and the broadcast station.

Following the papers, an inspection tour of the toll test room where program-handling equipment, ship-to-shore terminal apparatus, telephoto wire circuits, and other special services were demonstrated.

January 29, 1940, R. M. Walker, chairman, presiding.

Washington

P. A. de Mars, technical director of the Yankee Network, presented some "Observations on Coverage with Frequency-Modulated Waves."

The requirements of a broadcast system in regard to noise and fidelity of reproduction were first considered. The limitations of the present amplitude-modulated-wave system were pointed out and the advantages of the frequency-modulated-wave system stressed.

The installation at Paxton, Massachusetts, was described and the coverage of this frequency-modulated-wave transmitter was compared with that obtained from the standard broadcast stations in the same area. The effects of antenna heights both at the receiver and transmitter and the limitations introduced by the terrain between the two ends of the system were discussed.

Major Armstrong, who developed the system, discussed briefly the history of its development and the principles involved.

January 8, 1940, L. C. Young, chairman, presiding.

W. L. Webb, engineer in charge of the receiver and radio-compass engineering department of the Bendix Radio Corporation, presented his paper on "Design of Radio Receiving Equipment to Meet Special Requirements." This paper is summarized in the meeting of the Baltimore Section which appears elsewhere in this issue.

February 12, 1940, L. C. Young, chairman, presiding.

Personal Mention

The following members have informed us of changes in their company affiliations or titles to those given below.

Angus, George W.; Communications Superintendent, Pan American Airways, Treasure Island, San Francisco, Calif.

Campbell, Walter H.; Federal Telegraph Company, Newark, N. J.

Case, Myron D.; Engineer, National Broadcasting Company, San Francisco, Calif.

Cawein, Madison; Engineer, Farnsworth Television and Radio Corporation, Marion, Ind.

Cox, Claude R.; Chief Engineer, Victor J. Andrew Company, Chicago, Ill.

Craig, Palmer H.; Engineer, Philco Radio and Television Corporation, Philadelphia, Pa.

Deakin, Gerald; Bell Telephone Manufacturing Company, Antwerp, Belgium.

Dobbie, Leonard G.; Radiophysics Staff, Council for Scientific and Industrial Research, University of Sydney, Sydney, Australia.

Engel, Francis H.; Sales Engineer, RCA Manufacturing Company, Inc., Washington, D. C.

Fischer, Fred W.; Broadcast Engineering and Design, Westinghouse Electric and Manufacturing Company, Baltimore, Md.

Halloran, A. H.; Farnsworth Television and Radio Corporation, Fort Wayne, Ind.

Hemberger, Emil F., Jr.; Engineer, Muzak Corporation, New York, N. Y.

Kouchnerkavich, Thomas A.; Associate Radio Engineer, Civil Aeronautics Authority, Experimental Station, Indianapolis, Ind.

Marshall, Charles J.; Inspector of Engineering, Aircraft Radio Laboratory, Wright Field, Dayton, Ohio.

Mayer, Irving S.; Inspector, Signal Corps Aircraft Radio Laboratory, Wright Field, Dayton, Ohio.

McConnell, Robert A.; Physicist, Naval Aircraft Factory, Philadelphia, Pa.

Mellor, William N.; Communications Engineer, American Airlines, Jackson Heights, L. I., N. Y.

Miller, John M.; U. S. Naval Research Laboratory, Anacostia Station, Washington, D. C.

Miyakosi, Kazuo; Professor, Osaka Technical College, Sakai, Osaka, Japan.

Momotsuka, K.; Engineering Department, Nippon Hoso Kyokai Kojimachi, Tokyo, Japan.

Moore, William H.; Electrical Engineer, Canadian Industries, Ltd., Montreal, Que., Canada.

Peterson, Glen; Research Department, Phillips Petroleum Company, Bartlesville, Okla.

Ringham, Gordon B.; Radio Engineer, Rediffusion, Ltd., Wandsworth, London, S. W. 18, England.

Rybner, Jorgen; Professor of Telecommunication Technics, Royal Technical College, Copenhagen, Denmark.

Sherman, Warren K.; Lieutenant Commander, U.S.N.; *U.S.S. Blackhawk*, Asiatic Station, San Francisco, Calif.

Smeby, Lynne C.; Director of Engineering, National Association of Broadcasters, Washington, D. C.

Sterky, Hakan K. A.; Professor of Telegraphy and Telephony, Royal Technical University, Stockholm, Sweden.

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 April 30, 1940.

Transfer to Member

Adorjan, P., Coombe Gorse, Coombe Park, Kingston Hill, Surrey, England.

Chaffee, J. G., Bell Telephone Laboratories, Inc., 463 West St., New York, N. Y.

Dobbie, L. G., c/o Amalgamated Wireless, A/sia., Ltd., 554 Parramatta Rd., Ashfield, Sydney, Australia.

Sandretto, P. C., United Air Lines, 5959 S. Cicero Ave., Chicago, Ill.

Starr, C. H., 62 Woodfield Rd., Ealing, London W.5, England.

Admission to Member

Lee, E. S., 219 Furman St., Schenectady, N. Y.

Siling, P. F., Federal Communications Commission, Washington, D. C.

Admission to Associate (A), Junior (J), and Student (S).

Ackerman, E. G., (A) 35 Shelley Cres., Southall, Middx., England.

Allen, C. E., (A) 1831 Bailey Ave., Buffalo, N. Y.

Armitage, G., (A) 228 St. Helen's Ave., Toronto, Ont., Canada.

Arthur, G. M., (S) Beta Theta Pi House, Orono, Maine.

Atwood, H., Jr., (S) Martin Hall, West Virginia University, Morgantown, W. Va.

Aymond, E. F., (A) 3750 Urban Ave., Dallas, Tex.

Bark, R. S., (J) 1128 32nd, S., Seattle, Wash.

Baumgartner, W., (A) 2911 S.W. Barbur Blvd., Portland, Ore.

Berman, M., (J) 1002 E. 17th St., Brooklyn, N. Y.

Bershad, L., (S) 691 Gerard Ave., New York, N. Y.

Bond, L., (A) 138 Shippen St., Weehawken, N. J.

Bretzin, V. B., (A) 1223 Montorey St., N.S. Pittsburgh, Pa.

Brownson, R. O., (A) 3815 Beethoven St., Venice, Calif.

Burg, K. E., (A) 2114 N. Harwood, Dallas, Tex.

Carleton, H., (A) 432 Randolph St., N.W., Washington, D. C.

Cherry, S. J., (A) 442 S. 12th St., Newark, N. J.

Chin, P. H., (S) Box 504, West Lafayette, Ind.

Cooper, F. W., (A) 1010 N. 18th St., Kansas City, Kan.

Cox, W. B., (A) 2256—6th Ave., Fort Worth, Tex.

Cuccia, C. L., (S) 732 Forest, Ann Arbor, Mich.

Dobosy, J. F., (A) 1215 W. 20th St., Lorain, Ohio.

Ehmsen, T. V., (A) 0346 S.W. Texas, Portland, Ore.

Erickson, D. W., (J) Box 9, Greytown, Natal, South Africa.

Field, W. A., Jr., (S) 1518—34th Ave., Seattle, Wash.

Fisher, P. F., (S) 2627 Pasadena Ave., Detroit, Mich.

Forster, H. L., (A) 497 Cambridge St., Buffalo, N. Y.

Fortune, D., (A) 500 W. Huron St., Chicago, Ill.

Friend, B. L., (A) 1237—46th St., Des Moines, Iowa.
Geils, J. W., (S) 2121 Haight Ave., New York, N. Y.
George, J. M., (A) "Rheola," Broad Walk, Caerleon, Newport, Mon., England.
Granberry, D., (A) 2405 Langdon, Dallas, Tex.
Gray, L. F., (A) 214 Lazard Ave., Mount Royal, Montreal, Que., Canada.
Grimm, A. C., (S) 557 W. 148th St., New York, N. Y.
Hall, R. D., (A) Box 6, Naracoorte, South Australia.
Hansen, H. M., (S) 3240 Briggs Ave., Alameda, Calif.
Harris, F., (A) Olleros 3738, Dto. B., Buenos Aires, Argentina.
Heard, B. E., (A) 3008 Rosedale, Dallas, Tex.
Hemming, C. B., (A) Box 64, Parlin, N. J.
Hollifield, W. N., (A) 1914 Ashby St., Dallas, Tex.
Hughes, J. V., (S) 152 Dillon Hall, University of Notre Dame, Notre Dame, Ind.
James, S. D., (S) 806 Colorado, Pullman, Wash.
Jeffords, J. M., (A) 161-43—86th Ave., Jamaica, L. I., N. Y.
Jerman, W. J., (A) c/o Radio Station KWJJ, 622 S.W. Salmon St., Portland, Ore.
Jones, M. P., (A) 1311 Republic Bank Bldg., Dallas, Tex.
Kalb, H. N., (A) 245 Market St., San Francisco, Calif.
Kitchen, D. J., (A) 74 Commonwealth, Buffalo, N. Y.
Kwietniewski, C. J., (A) 17 Sunnyside Ave., Buffalo, N. Y.
Libby, H. L., (A) Radio Station KWSC, Pullman, Wash.
Lund, N., (A) 365 N. Walnut St., East Orange, N. J.
Mathis, J. D., (A) 802 Telephone Bldg., Dallas, Tex.
McNeely, J. S., (A) 805 Telephone Bldg., Dallas, Tex.
Meek, T. J., Jr., (S) 68 Spadina Rd., Toronto, Ont., Canada.
Miller, I. T., (S) 2313 Tilbury St., Pittsburgh, Pa.
Mills, T. L., (S) 531 N. 11th, Corvallis, Ore.
Mitchell, J. K., (A) 53 Greenwood Ave., East Orange, N. J.
Moore, S. A., (S) 516—22nd St., Ogden, Utah.
Morrison, W. C., (S) 120 E. Davenport St., Iowa City, Iowa.
Newburgh, H., (A) R.F.D. 5, Ann Arbor, Mich.
Ostaff, W., (S) Bethel Hall, Ohio University, Athens, Ohio.
Paananen, R. A., (J) General Delivery, Marquette, Mich.
Packard, K. N., (S) 731 County St., New Bedford, Mass.
Parker, T. E., (S) Box 896, Albuquerque, N. M.
Pifer, M. J., (A) Brompton Rd., Williamsville, N. Y.
Pontius, J. C., (A) 15 Youngs Rd., Williamsville, N. Y.
Ragland, H. B., (A) 1105 Flower Ave., Takoma Park, Md.
Rich, E. S., (S) 25 Grove St., Orono, Maine.
Schawlow, A. L., Jr., (S) 51 Alameda Ave., Toronto, Ont., Canada.
Schley, W. H., (A) 5704 Hudson St., Dallas, Tex.
Schwerling, A. G., (A) 1423 Elkton Pl., Cincinnati, Ohio.
Seifert, W. W., (S) 1716 Highland Ave., Troy, N. Y.
Sherron, R. J., Jr., (A) Communications, Pan American Airways, Baltimore, Md.
Spargo, P. W., (A) 405 W. 33rd St., Vancouver, Wash.
Speck, J. H., (A) Radio Station KRLD, Dallas, Tex.
Stoerck, L. A., (A) Dodge Radio Institute, Valparaiso, Ind.
Sussman, B. B., (S) 50 Brunswick Ave., Troy, N. Y.
Swan, E. O., (A) 444 University Ave., Toronto, Ont., Canada.
Toman, G. W., (S) 643 Maxwelton Ct., Lexington, Ky.
Torrey, W. H., (A) c/o Radio Station KEYO, Lubbock, Tex.
Turbot, H. R., (S) 219B Quadrangle, Iowa City, Iowa.
Van Wambeck, S. H., (A) c/o Rice Institute, Houston, Tex.
Wallace, W. F., Jr., (A) Communications, Pan American Airways, Brownsville, Tex.
Willms, G., (S) 19 Lawn Ave., Albany, N. Y.

Books

Aircraft Radio and Electrical Equipment, by Howard K. Morgan.

Pitman Publishing Company, New York, N. Y. Price, $4.50. 374 pages, 214 figures.

Morgan has written an informative book exclusively on airplane radio equipment and the more important nonradio airplane electrical equipment which aviation radio servicemen, flight personnel, and others whose duties require a comprehensive understanding of airplane radio facilities used by the transport air lines will find of great interest and value. The radio engineer designing airplane radio apparatus will find the book useful since several chapters have been devoted to descriptions of apparatus used currently on transport airplanes in the United States.

The author is superintendent of communications for Transcontinental and Western Air, Inc., and is well qualified by background of experience to set forth his subject with emphasis on the aspects of airplane radio apparatus most important to the air lines. The main topic, Airplane Radio Apparatus, is approached with consideration for the beginner, first taking him through several preliminary chapters outlining the fundamental principles of electric circuits before explaining the specialized radio circuits found in transmitters and receivers. This approach, which is made through the use of hydraulic analogies, should bring the elementary principles of the subject within the grasp of a wide group of interested technicians, whether he be among the flight personnel, service group, or the young man looking for a place to head in.

Schematic circuit diagrams and values of apparatus elements are given for a great many representative radio units, receivers, transmitters, and radio compasses. The diagrams in most cases are printed on large folded sheets, which makes the circuit clear and the designations distinct. Probably not outside of manufacturers' bulletins will similar information be found and nowhere will the compact equivalent accumulation be found for ready reference.

Airplane radio apparatus is used for both communication and navigation purposes. These subjects are treated separately. The discussion on the latter will help flight personnel to comprehend better some of the idiosyncrasies of the radio range signals resulting from transmission difficulties and maladjustment of apparatus. A brief presentation is made of the elements of the radio instrument landing system, including the ultra-high-frequency marker beacons.

An important problem to all air-line organizations, that of maintenance and inspection of airplane radio equipment, is discussed in the final chapter and there are included sample sheets of inspection reports, failure reports, repair reports, etc.

To assist the student reader in checking his understanding of the material presented in each chapter, there is given at the end a series of true-or-false questions with the key to the correct answers at the end of the book.

The book is well printed and contains valuable information in a practical and usable form. One adverse comment relates to Morgan's propensity to carelessness in adherence to the recognized usage of words, partly due, no doubt, to his desire to obtain brevity but tending to confuse the beginner who does not have a background for discretion in the recognized technical meaning of words.

De Loss K. Martin
Bell Telephone Laboratories
New York, N. Y.

The Radio Amateur's Handbook (Seventeenth (1940) Edition), by the Headquarters staff of the A.R.R.L.

Published by the American Radio Relay League, Inc., West Hartford, Conn. 576 pages, including 8-page topical index and 120-page catalog section of amateur radio equipment. Approximately 830 illustrations and 86 charts and tables. Price, paperbound, $1.00 in continental United states, $1.25 elsewhere; buckrambound, $2.50. Spanish edition, $1.50.

Within its 456 pages, the 1940 edition of the Radio Amateur's Handbook compresses a wealth of helpful information and instructive material for the radio amateur. It is compiled by the competent editors of *QST* who know exactly the current interests and needs of the transmitting radio amateur. In this connection, it is to be noted that it is the transmitting amateur and not the amateur experimenter who receives the greater attention today.

Rearrangement of the chapter content has given the Handbook a logical sequence on a straight-through reading. Related charts and tables are included in chapters where their use is pertinent, rather than in an appendix as in past editions.

The nine or ten chapters devoted to the theoretical considerations are excellent. Naturally, they are in the form of a digest of radio theory, but the widespread popularity of past editions of the Handbook shows that this is probably the manner in which the radio amateur wishes to obtain his information.

The chapters devoted to the construction of transmitters and power supplies are marked by the attention given to safety measures and devices for the prudent handling of the high voltages involved. It is deplorable that it required the death of Mr. Ross Hull, able editor of past editions of the Handbook, to bring home the dangers of neglect in this respect.

It is evident from the construction articles that the 1940 amateur must have or acquire some ability as a metal worker in addition to his skill with a soldering iron, as the wood panel type of construction has practically disappeared with the increased need for shielding the components.

Considerable material in the Handbook is taken from the pages of *QST*. Such contributions sometimes contain more opinion than fact and for the amateur who takes his Handbook as gospel, this is unfortunate. This edition shows evidence of more careful editing in this respect than past editions.

There are errors like the transposition of diagram and subtitle in figures 902 and 904, and the circuit error in figure 2905, page 403 is repeated from last year's Handbook with all fidelity, but they are relatively unimportant. The 1940 radio amateur will find that the Handbook holds the answers to most of his questions.

HOWARD A. CHINN
Columbia Broadcasting System
New York, N. Y.

Complex Variable and Operational Calculus with Technical Applications, by N. W. McLachlan.

The University Press, Cambridge, England; The Macmillan Company, New York, N. Y. xi+355 pages. Price $6.50.

The contents of this book are described with unusual accuracy by the title. The first part, Theory of Complex Variable, occupies 112 pages and presents a digest of the theory of contour integration in the complex plane, with particular attention to the integration of the gamma, error, and Bessel functions as well as certain others arising in technical applications. The second part, Theory of Operational Calculus, occupies 50 pages and treats the subject solely from the point of view of what Carson calls the infinite integral theorem and which the author designates as the Mellin Inversion Theorem. Other approaches to the operational calculus are ignored except for a brief general statement in the preface. The third part, Technical Applications of Parts I and II, occupies 131 pages (including 11 pages of Examples to be worked out by the reader), and discusses in some detail, among other matters, the solution of certain problems in general electrical circuit theory, in radio and television receivers (including loud speakers), in electrical transmission lines and wave filters, in airplane dynamics, and in heat conduction. In addition to the above three main parts there is a fourth part occupying 49 pages consisting of Appendixes detailing mathematical proofs of matters referred to in the text, a list of principal formulas, and a bibliography. Each of these parts is furnished with a separate preface and an adequate subject index completes the volume.

The author has introduced one notational novelty which seems to the reviewer to have some merit. This is a symbol signifying "the operational form of" which consists of the equality sign with a semicircular arc connecting those ends pointing toward the operational form. The printer may not welcome this addition to his type case, but the new symbol certainly saves much circumlocution.

As a whole, the reviewer is of the opinion that while this book, largely owing to being confined to a single one of several points of approach to the subject, will not replace such treatises as those of Carson or Bush for example, will nevertheless be found to be a useful addition to the bookshelves of the mathematical engineer. Particularly for those who prefer the logic of deductive processes to the inductive methods of Heaviside, and who are content to get the historical perspective of the subject from other sources.

LYNDE P. WHEELER
Federal Communications Commission
Washington, D. C.

Report of the Secretary—1939

The following information is published so the membership may have knowledge of the activities and developments of the Institute during 1939.

Membership

The paid membership at the end of 1939 was 5612, an increase of approximately four per cent. The annual membership totals throughout the life of the Institute are plotted in Fig. 1.

The membership located outside of the United States and its possessions has shown a reduction and is now 21.5 per cent of the total compared with 23.6 per cent in 1938. Most of the loss has occurred in countries which are now engaged in military activities.

There were 790 new members admitted, an increase of thirteen per cent over the number for 1938. Approximately forty per cent of the new members were of Student grade.

Three Fellows and sixty Members were transferred or admitted to those grades. Table I gives a breakdown of the distribution of members by grades at the end of the year.

Proceedings

Volume 27 of the PROCEEDINGS was the first to appear in the enlarged format. It contained 800 pages of editorial material which are equivalent to approximately 1760 pages of the small size. Data are given in Fig. 2 on the amount of material published yearly in the PROCEEDINGS.

At the start of the year there was a large quantity of material approved for publication on hand and the time required between the receipt of a paper and its publication in the PROCEEDINGS was about eight months. This situation became worse as the year advanced and the Board of Editors made a detailed examination of the problem.

All pending material was reviewed by a special committee of editors and a large number of manuscripts were returned to the authors for abridgment. The requirements for acceptance were raised and the number of manuscripts rejected increased. As a result, all of the approved material on hand at the time the December issue was scheduled was included in it.

TABLE I

MEMBERSHIP DISTRIBUTION BY GRADES

Grade	Number	Per Cent
Fellow	159	2.8
Member	660	11.8
Associate	4362	77.7
Junior	32	0.6
Student	399	7.1
	5612	100.0

There were seventy-four papers reviewed by the Papers Committee and one hundred considered by the Board of Editors. The Co-ordinating Committee of the Board of Editors handled seventy papers. Forty-five papers were approved, nineteen were returned to the authors for revision, twenty-three for abridgment, and thirty-three were rejected. In addition, thirty-one book reviews were prepared and published.

Sections

Two new sections of the Institute were established, one in Baltimore, Maryland and the other in Buenos Aires, Argentina. This increases the number of sections to twenty-three. Table II gives data on section meetings and membership.

President Heising visited nineteen of the twenty-three Institute sections. This represents the greatest amount of personal contact between an Institute officer and the sections which has ever occurred in a single year.

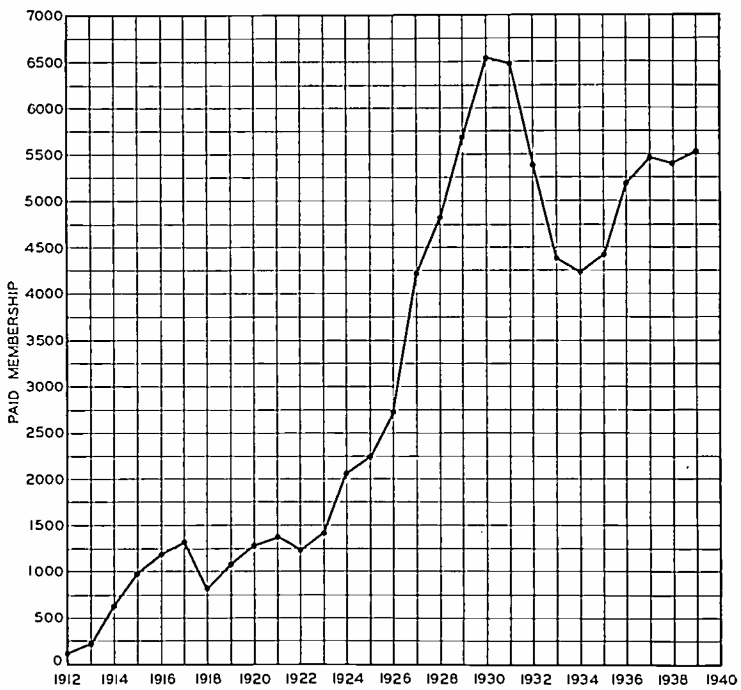


Fig. 1

Meetings

Our sections held 174 meetings. In addition, eight meetings were held in New York and there were four meetings of the convention type.

A joint meeting with the American Section of the International Scientific Radio Union (U.R.S.I.) was held in Washington, D.C., on April 28 and 29. A program of eighteen papers was presented during the two days and the attendance approximated 150.

The first national convention of the Institute held west of Chicago took place in San Francisco on June 27, 28, 29, and 30. Of the twenty-eight papers which were presented, only eight came from authors located on the Pacific Coast. In addition, an unexpectedly large portion of the 331 men present was from the Eastern section of the country giving to the convention a true national aspect.

The Fourteenth Annual Convention was held in New York City on September 20, 21, 22, and 23. The four-day meeting permitted a greater amount of time for visiting the Fair and also avoided the necessity of running parallel technical sessions. Twenty-eight papers were presented. The registration totaled 1615

TABLE II

SECTION MEMBERSHIP AND MEETINGS

	Membership Dec. 31, 1939	Meetings Held 1939	Meetings Held 1938	Meetings Held 1937	1939 Average Attendance*	1939 Per Cent Attendance
Atlanta	37	10	11	10	29	78
Baltimore**	80	2	—	—	223	279
Boston	220	6	5	6	150	68
Buenos Aires**	36	1	—	—	40	111
Buffalo-Niagara	36	3	10	10	54	150
Chicago	283	8	14	10	130	46
Cincinnati	86	10	10	8	59	69
Cleveland	73	11	6	7	55	75
Connecticut Valley	81	4	6	7	104	128
Detroit	96	9	10	10	73	76
Emporium	86	12	12	15	43	50
Indianapolis	55	3	8	10	78	142
Los Angeles	227	10	11	8	103	45
Montreal	84	7	10	5	80	95
New Orleans	18	2	3	6	27	150
Philadelphia	316	8	9	8	212	67
Pittsburgh	53	12	11	9	30	57
Portland	57	11	1	—	41	72
Rochester***	38	7	10	12	—	—
San Francisco	208	12	17	17	41	20
Seattle	53	8	9	10	62	117
Toronto	80	8	11	12	74	93
Washington	300	10	10	9	152	51
	2603	174	194	189		

* Does not include joint meetings with other societies. ** Established October, 1939.
*** Seven meetings credited for 1939 Rochester Fall Meeting. All meetings held jointly with other societies.

men. Thirty-four manufacturers participated in the exhibition.

At the Rochester Fall Meeting which was held on November 13, 14, and 15, seventeen papers were presented. An inspection trip was made to the frequency-modulated-wave transmitting station of the Stromberg-Carlson Telephone Manufacturing Company. An exhibition of material of interest to engineers was part of the meeting. The attendance at the meeting was 456.

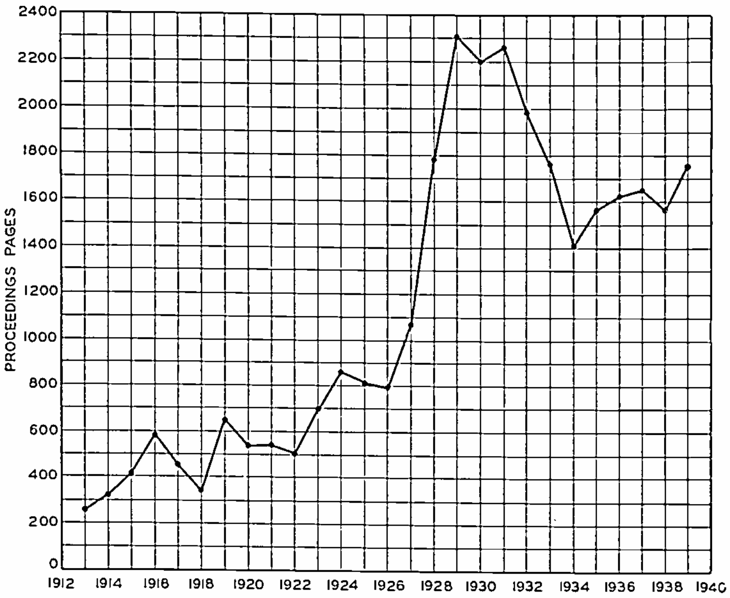


Fig. 2

Board of Directors

The Board of Directors, which consists of twenty members and is responsible for the management of the Institute, met ten times during the year.

Committees

Much of the Institute work is accomplished by committees of which there are twelve dealing with general problems, twenty to handle technical subjects, and during 1939, five were established or in operation to consider special problems. These committees held seventy-six meetings.

Constitution and Bylaws

The Constitution circulated to the membership late in 1938 for balloting was approved and became effective on March 31, 1939. At the September meeting of the Board of Directors new Bylaws, prepared on the basis of the new Constitution, were adopted. Both documents were published in the December issue of the PROCEEDINGS.

Awards

At the Awards Luncheon which was held during the Fourteenth Annual Convention, the Institute Medal of Honor was presented to Sir George Lee, recently retired Engineer-in-Chief of the British Post Office, for his accomplishments in promoting international radio services and in fostering advances in the art and science of radio communication. Sir George was unable to be present to receive the award and it was accepted in his behalf by a member of the British Consulate staff. By means of the transatlantic telephone system, with the establishment of which Sir George was so intimately connected, the speech of presentation by President Heising was transmitted to Sir George in London and his reply was heard by all present at the luncheon.

The Morris Liebmann Memorial Prize was awarded to Harald Trap Friis for his investigations in radio transmission including the development of methods of measuring signals and noise and the creation of a receiving system for mitigating selective fading and noise interference. Mr. Friis was present to receive the award at the luncheon.

Finances

At the end of this report will be found a balance sheet prepared by our auditor. It gives comparative figures for 1938 and 1939. Fig. 3 shows annual income and expense figures for the life of the Institute.

Headquarters Staff

The headquarters staff now numbers eleven, one fewer than employed last year. Of the eleven, six have been with the Institute for ten or more years and one for nine years.

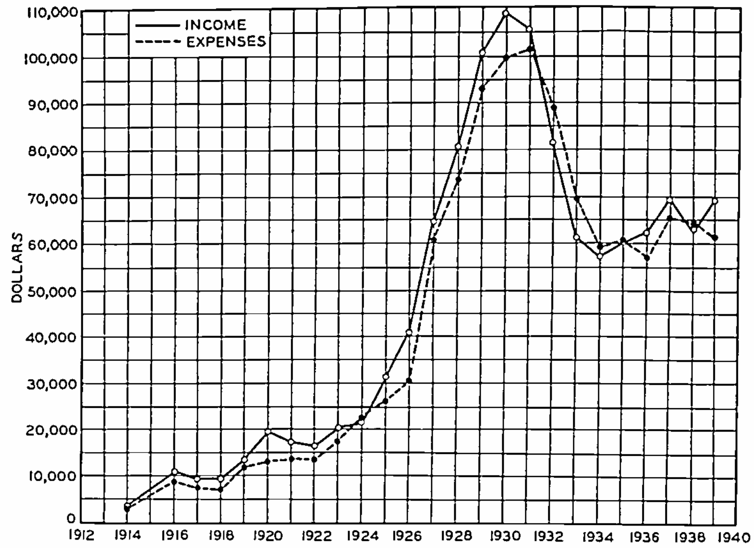


Fig. 3

Deaths

We list below with regret the names of twenty members whose deaths were reported during 1939.

Ashbrook, R. B.	Kennelly, A. E.
Crosby, G. L.	Neville, T. P.
DeLaszlo, S. P.	Paulsen, L. A.
Dill, G. C.	Rogers, E. S.
Douthit, M. L.	Ross, J. D.
Ellingson, H. J.	Rudd, Warren
Gunther, W. J.	Seletzky, A. C.
Henning, C. I. B.	Stadler, J. C.
Hoyt, C. F.	Sterba, E. J.
Janke, A. H.	Wisner, F. L.

Acknowledgment

Only relatively few members are able to serve on the Board of Directors or committees of the Institute. Those who do play an active part in the operation and management of the organization deserve the sincere thanks of all others who are unable to participate so directly in the operation of their Institute.

Respectfully submitted,

Harold P. Westman

HAROLD P. WESTMAN
Secretary

February 2, 1940.

The Institute of Radio Engineers, Inc.
Comparative Balance Sheet

December 31, 1939 and 1938

	December 31, 1939	December 31, 1938	Increase Decrease
Assets			
Current Assets			
Cash	$21,230.43	$21,108.69	$ 121.74
Accounts Receivable—Current			
Dues	489.52	336.00	153.52
Advertising	702.66	358.00	344.66
Reprints	146.71	64.36	82.35
Inventory (as submitted by the management)	7,542.29	7,285.79	256.50
Accrued Interest on Investments	185.83	285.28	**99.45**
Total Current Assets	$30,297.44	$29,438.12	$ 859.32
Investments—At Cost (Market Value December 31, 1939—$29,205.63)	49,922.12	46,922.12	3,000.00
Furniture and Fixtures After Reserve For Depreciation	2,245.00	2,131.76	113.24
Prepaid Expenses			
Unexpired Insurance	87.64	45.52	42.12
Stationery Inventory—Estimated	200.00	200.00	
Convention Expense	65.86	103.54	**37.68**
Total Assets	$82,818.06	$78,841.06	$3,977.00

Liabilities and Surplus	December 31, 1939	December 31, 1939	Increase Decrease
Accounts Payable	$ 252.61	$ 2,699.48	**$2,446.87**
Suspense	24.07	16.22	7.85
Advance Payments			
Dues	2,966.06	1,438.44	1,527.62
Subscriptions	2,571.38	4,055.86	**1,464.48**
Advertising		4.00	**4.00**
New York State Income Tax Withheld from Employees	38.00		38.00
Total Liabilities	$ 5,852.12	$ 8,194.00	**$2,341.88**
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	58,571.39	58,957.06	$ **385.67**
Add—Operating Profit or Loss for the Years	6,318.88	**385.67**	6,704.55
Surplus—December 31	64,890.27	58,571.39	6,318.88
Total Liabilities and Surplus	$82,818.06	$78,841.06	$3,977.00

Patterson and Ridgeway
Certified Public Accountants
74 Trinity Place
New York, New York

Contributors

W. L. Barrow

W. L. Barrow (A'28) was born in Baton Rouge, Louisiana, on October 25, 1903. In 1926 he received the B.S. degree in electrical engineering from Louisiana State University, and in 1929 the M.S. degree from Massachusetts Institute of Technology. He was a Redfield Proctor Fellow in Physics at the Technische Hochschule in Munich, Germany, where, in 1931, he received the Sc.D. degree in physics. Serving from 1931 to 1936 as an instructor in the Communications Division of Massachusetts Institute of Technology and as a member of the Round Hill research group, Dr. Barrow was appointed professor of

J. G. Brainerd

electrical communications in 1936. He is a member of the American Institute of Electrical Engineers.

❖

John Grist Brainerd (A'33–M'39) was born in 1904. From 1923 to 1925 he was a police reporter on the *Philadelphia North American*. He received the B.S. degree from the University of Pennsylvania in 1925 and the Sc.D. degree in 1934. Since 1925 he has been instructor and assistant professor at the Moore School of Electrical Engineering of the University of Pennsylvania. During 1935 and 1936 Dr. Brainerd was Engineer and Assistant State Director, Power Division, Public Works Administration.

❖

Andrew V. Haeff (A'34) received the degree of Electrical and Mechanical Engineer from the Russian Polytechnic Institute at Harbin, China, in 1928. That same year he came to the United States and majored in electrical engineering at the California Institute of Technology

Andrew V. Haeff

where he obtained the M.S. degree in 1929 and the Ph.D. degree in 1932. During 1932–1933, Dr. Haeff was a special Research Fellow in the Electrical Engineering Department of the California Institute of Technology, engaging in research work on ultra-high-frequency problems. In 1934 he joined the RCA Manufacturing Company where he is working in the same field

❖

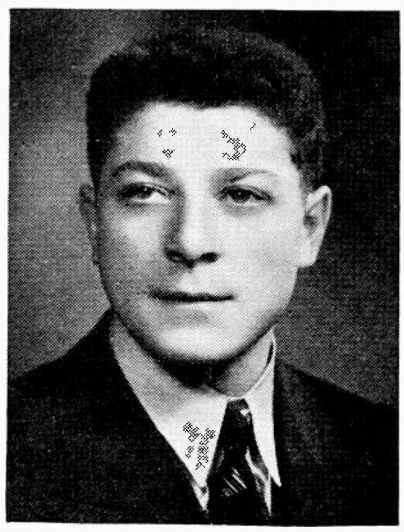
Leon S. Nergaard (A'29–M'38) was born at Battle Lake, Minnesota, on September 2, 1905. He received the B.S. degree in electrical engineering from the University of Minnesota in 1927, the M.S. degree from Union College in 1930, and the Ph.D. degree from the University of Minnesota in 1935. From 1927 to 1930 Dr. Nergaard was in the Research Laboratory and Vacuum-Tube Engineering Department of the General Electric Company; from 1930 to 1933 he was a teaching assistant in the Department of Physics at the University of Minnesota; since 1933 he has been in the Research and Develop-

Leon L. Nergaard

ment Laboratory of the RCA Manufacturing Company, RCA Radiotron Division. He is a member of Sigma Xi and the American Physical Society.

❖

Carl Shulman (S'39) was born on January 12, 1917. He received the S.B. degree in electrical engineering in 1938 and the S.M. degree in 1939 from Massachusetts Institute of Technology. Since 1939 Mr. Shulman has been a part-time special student in the graduate school of electrical engineering of the Massachusetts Institute of Technology. He is an Associate member of Sigma Xi.



Carl Shulman

❖

For biographical sketches of T. R. Gilliland, S. S. Kirby, and N. Smith, see the Proceedings for January, 1940.

Current Literature

New books of interest to engineers in radio and allied fields—from the publishers' announcements.

A copy of each book marked with an asterisk (*) has been submitted to the Editors for possible review in a future issue of the Proceedings of the I.R.E.

* BBC Handbook 1940. London: The British Broadcasting Corporation, 1940. 125+3 index pages, illustrated, $4\frac{3}{4}\times7\frac{1}{4}$ inches, cloth. 2 shillings.

* Einfuhrung in die Theorie der Rundfunksiebschaltungen (Introduction to the Theory of Broadcast Filters). By Richard Feldtkeller, Professor and Director of the Institutes for Electrical Communications, Technische Hochschule, Stuttgart. Leipzig: S. Hirzel, 1940. ix+168 pages, illustrated, 6×9 inches, paper. 10.80 rm.

The History of the Institution of Electrical Engineers 1871–1931. By Rollo Appleyard. London: The Institution of Electrical Engineers, October, 1939. 342 pages, illustrated, 7×10 inches, cloth. 18 shillings, 6 pence.

* The Oscillator at Work. By John F. Rider. New York: John F. Rider, Inc., January, 1939. xi+243 pages, illustrated, $5\frac{1}{4}\times8$ inches, cloth. $1.50.

* Principles of Television Engineering. By Donald G. Fink, Managing Editor, "Electronics." New York: McGraw-Hill Company, Inc., 1940. xii+515 +5 appendix +19 index pages, illustrated, 6×9 inches, cloth. $5.00.

Radio Interference Suppression. By Gordon W. Ingram. London: Electrical Review, Ltd., August, 1939. 162 pages, illustrated, $5\times7\frac{1}{2}$ inches, cloth. 5 shillings.

* Safety Rules for Radio Installations: Comprising Part 5 of the Fifth Edition National Electrical Safety Code, National Bureau of Standards Handbook H35. Washington: Superintendent of Documents, December, 1939. 25 pages, $5\times7\frac{1}{2}$ inches, paper. 10 cents.

* Specifications for Heavy-Walled Enameled Round Copper Magnet Wire C8.20–1939. New York: American Standards Association, November, 1939. 7 pages, $7\frac{3}{4}\times10\frac{3}{4}$ inches, paper. 20 cents.

* Specifications for Weather-Resistant Saturants and Finishes for Aerial Rubber—Insulated Wire and Cable C8.19–1939. New York: American Standards Association, November, 1939. 7 pages, $7\frac{3}{4}\times10\frac{3}{4}$ inches, paper. 20 cents.

* Television: The Electronics of Image Transmission. By V. K. Zworykin and G. A. Morton, Electronics Research Laboratory, RCA Manufacturing Company. New York: John Wiley & Sons, Inc., London: Chapman & Hall, Ltd., 1940. xi+631+14 index pages, illustrated, 6×9 inches, cloth. $6.00.

Booklets, Catalogs and Pamphlets

The following commercial literature has been received by the Institute.

FREQUENCY MODULATION • • • *Radio Engineering Laboratories, Long Island City, New York. Booklet 259, 20 pages+cover, 8½×11 inches.* A general description of 4 frequency-modulated-wave transmitters and a receiver.

FREQUENCY MODULATION • • • *General Electric Company, Schenectady, New York, Bulletin GEA-3327, 4 pages, 8×10½ inches.* Technical information on the 4GF1A1 frequency-modulated-wave transmitter.

INSULATION TESTING • • • *Associated Research, Incorporated, 16 Nprth May Street, Chicago, Illinois. Bulletin 201, 6 pages, 8½×11 inches.* Description of a combined ohmmeter and 500-volt leakage resistance measuring instrument in which the high voltage is supplied by a battery-operated synchronous vibrator.

LOW-RESISTANCE MEASUREMENTS • • • *James G. Biddle Company, 1211 Arch Street, Philadelphia, Pennsylvania. Bulletin 1635. 8 pages, 7¾×10½ inches.* Specifications and operating directions for a new instrument for measuring very low resistances.

RECORDING • • • *The Brush Development Company, 3322 Perkins Avenue, Cleveland, Ohio.* "Brush Strokes," *December, 1939, 8 pages, 8½×11 inches.* Contains an article. "Noise Reduction in Disc Records Through Constant Amplitude Recording."

TELEVISION RECEIVERS • • • *Aerovox Corporation, New Bedford, Massachusetts.* "The Aerovox Research Worker," *October, November, and December, 1939, 4 pages (each), 8½×11 inches.* Contains Parts 3, 4, and 5 of a summary of television-receiver circuits for servicemen and others interested in general survey information.

TUBE DATA (AMPEREX) • • • *Amperex Electronic Products, Incorporated, 79 Washington Street, Brooklyn, New York. Catalog Sheets, 8 pages, 8½×11 inches.* Specifications on 4 power tubes; 279A, 222A, 232C, and 846.

TUBE DATA (GE) • • • *General Electric Company, Schenectady, New York. Bulletin 6900, 4 pages, 8×10½ inches.* A table of characteristics of power tubes and mercury-vapor rectifiers.

TUBE DATA (RCA) • • • *RCA Manufacturing Co., Inc., Harrison, New Jersey. Bulletin 1275B, 12 pages, 8½×11 inches.* Characteristics chart and socket connections for receiving tubes.

REACTANCE AND DECIBEL CHART • • • *UnitedTransformer Corporation, 150 Varick Street, New York, New York. 2 pages, 8½×11 inches.* A convenient chart printed on heavy cardboard. On one side, "Decibels vs. Voltage and Power"; on the other side a nomograph relating reactance, frequency, capacitance, and inductance.

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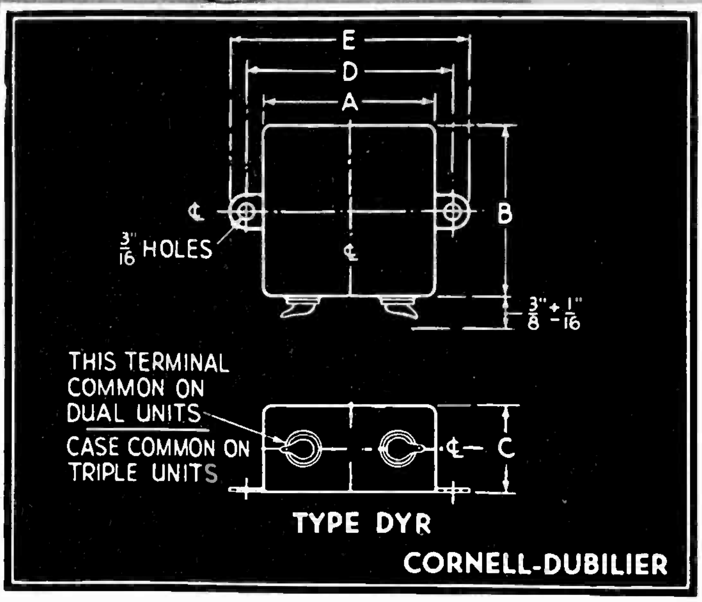

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