Parametric Devices and Masers: An Annotated Bibliography*

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Preface

THIS bibliography is restricted to books and periodical articles published prior to October, 1959. No attempt has been made to include the voluminous material to be found in technical reports, patents or similar sources.

Although the greatest portion of the bibliography has to do with microwave devices, the references do include some devices operating outside of the microwave frequency range, such as the optical, infrared and radio-frequency masers, and the parametrons.

Appreciation is expressed to Drs. M. Arditi and T. B. Warren of ITT Laboratories for their assistance in reviewing the categories into which the references were classified.

Table of Contents

Bibliography

I. Parametric Devices and Masers—Review Articles

[1] Anderson, P. W.
The reaction field and its use in some solid-state amplifiers.
Journal of Applied Physics, 28(9): 1049–1053; September, 1957.
Discussion of phenomena of the radiation reaction field and how it may be used in two solid-state amplifiers (Bloembergen's 3 energy-level type and Suhl's ferromagnetic type).

[2] Beam, R. E. and Brodwin, M. E.
Report of advances in microwave theory and techniques in U.S.A.—1958.
IRE TRANSACTIONS ON MICROWAVE THEORY AND TECHNIQUES, MTT-7(3): 308–327; July, 1959.
Includes a review of developments in masers and parametric devices, and cites 55 references of the U. S. publications in 1958.

[3] Damon, R. W.
How the maser operates. Part I—Maser shows promise, some drawbacks. Part II—Maser's potential rests on further work.
Aviation Week, 67(7): 76, 77, 81, 82, 87, 88; August 19, 1957. 67(8): 91, 92, 96, 99, 101, 104; August 26, 1957.
An informative article about the operating principles of the new atomic amplifiers (masers and parametric) with some remarks about their potentialities and limitations.

[4] Heffner, H.
Masers and parametric amplifiers.
1958 WESCON CONVENTION RECORD, (pt. 3): 3–8.
Reviews principles of both types of devices, then evaluates the progress being made in their development and comments on their relative value.

[5] Heffner, H.
Masers and parametric amplifiers.
Microwave Journal, 2(3): 33–40; March, 1959.
Discusses the theory and operation of all types of masers and parametric devices. Operational performance figures are given for various experimental models.

[6] Heffner, H.
Solid state microwave amplifiers.
IRE TRANSACTIONS ON MICROWAVE THEORY AND TECHNIQUES, MTT-7(1): 83–91; January, 1959.
Reviews the operation of both solid-state masers and parametric amplifiers and their performance. Includes a bibliography of 121 items.

[7] Holahan, J.
Solid state microwave amps (amplifiers) promise milli-microwatt reception.
Aviation Age, 29(6): 140–149; June, 1958.
A review of solid-state masers and parametric amplifiers.

[8] Maguire, T.
New microwave systems using low-noise devices.
Electronics, 32(34): 27–30; August 21, 1959.
Reviews the development of masers and parametric amplifiers, particularly use of the latter in military communications systems, as presented in papers at the PGMTT National Symposium held at Harvard University in 1959. Applications of tunable packaged masers are also reviewed.

[9] Matthei, W. E.
Recent advances in solid state receivers.
Microwave Journal, 2(1): 19–24; January, 1959.
Reviews the state of the art regarding solid-state masers and the diode and ferrite types of parametric amplifiers. Limitations and applications are pointed out.

[10] Mikaelian, A. L.
The problem of development of ferrite microwave amplifiers (In Russian).
Radiotekhnika i Elektronika, 3(11): 1323–1347; November, 1958.
A general review of the theory and development of solid-state masers and parametric devices.

[11] Parametrics and masers; questions and answers.
Electronic Industries, 18(3): 238–240, 243; March, 1959.

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Gives brief answers to basic questions about the operation and uses of such devices.

[12] Rostas, E. and Hulster, F.
Microwave amplification by means of intrinsic negative resistance.
Proceedings of the Institution of Electrical Engineers, 105B (supplement 11): 665–673; May, 1958.
Presents the theory of operation of microwave negative resistance amplifiers, including their bandwidth and noise factor. Points out their connection with parametric devices and masers.

[13] Salzberg, B.
Masers and reactance amplifiers—basic power relations.
Proceedings of the IRE, 45(11): 1544–1545; November, 1957.
Presents an alternative simple and nonquantum mechanical derivation of the power relations developed by J. M. Manley and H. E. Rowe (see [144]). These relations are of importance in connection with parametric amplifiers.

[14] Some recent solid state device developments in the U.S.A.
British Communications and Electronics, 6(7): 528–530; July, 1959.
A brief general review, including masers and parametric devices.

[15] Stevens, K. W. H.
Atomic and molecular generators—introduction.
Proceedings of the Institution of Electrical Engineers, 105b (supplement 11): 674–677; May, 1958.
Explains the principles of operation of both parametric devices and masers and then compares them. A discussion of terminology follows.

[16] Toth, R. C.
Toward improved missile communications.
Astronautics, 2(1): 54–55, 112–113; August, 1957.
Brief description of work being done by Bell Telephone Laboratories on ferromagnetic and maser amplifiers. Discusses their advantages and disadvantages.

[17] Von Hippel, A. R.
Molecular Science and Molecular Engineering.
John Wiley and Sons, Inc., New York, N. Y., 446 pp.; 1959.
Includes a chapter, written by J. W. Meyer, on parametric amplifiers and masers. Reviews the theory of the devices, gives examples of typical operational parameters, and discusses requirements for maser materials.

[18] Wittke, J. P.
New approaches to the amplification of microwaves; masers and the parametric amplifier.
RCA Review, 18(4): 441–457; December, 1957. Also in *Proceedings of the National Electronics Conference*, 13: 610–623; 1957.
Gives a description and discussion of basic principles of operation of the two types of molecular-microwave amplifiers—the maser and the parametric amplifier.

II. Parametric Devices

Review Articles

[19] "Cathode Ray," pseudonym.
Mavars—another kind of quiet microwave amplifier.
Wireless World, 65(5): 242–246; May, 1959.
Reviews the basic principles of parametric amplifiers, using simple electrical and mechanical analogs to explain their operation. Recent developments are reviewed.

[20] Weber, S.
The MAVAR: a low noise microwave amplifier.
Electronics, 31(39): 65–71; September 20, 1958.
Recent developments have resulted in three major types of mavar—the ferromagnetic, the variable capacitance, and the electron beam. Descriptions, characteristics, etc., are included for all three types.

Electron Tube Types

[21] Adler, R., Hrbek, G., and Wade, G.
A low-noise electron-beam parametric amplifier.
Proceedings of the IRE, 46(10): 1756–1757; October, 1958.
Reports results of further experimentation on electron tubes using fast-wave parametric amplification by means of a new electrode structure, operating in the 500-mc range.

[22] Adler, R.
Parametric amplification of the fast electron wave.
Proceedings of the IRE, 46(6): 1300–1301; June, 1958.
Results of an experiment using parametric amplification between two fast-wave beam coupling devices.

[23] Ashkin, A., Bridges, T. J., Louisell, W. H., and Quate, C. F.
Parametric amplification of space-charge waves.
Proceedings of the Institution of Electrical Engineers, 105B (supplement 11): 649–651; May, 1958.
Describes an amplifier using an electron beam passing through a cavity to implement a traveling-wave parametric amplifier. It provides a method of amplifying the fast space-charge wave rather than the slow space-charge wave.

[24] Ashkin, A.
Parametric amplification of space charge waves.
Journal of Applied Physics, 29(12): 1646–1651; December, 1958.
Describes the operation of a movable cavity-type device. With the pump frequency twice the signal frequency, an increase of 41 db was observed in the signal over a ten-inch length of beam. With the pump frequency lower than the signal frequency, an increase of the signal by 30 db over a 9.2-inch length of beam was observed.

[25] Ashkin, A., Bridges, T. J., Louisell, W. H., and Quate, C. F.
Parametric electron beam amplifier.
1958 IRE WESCON Convention Record, (pt. 3)13–22.
Describes the theory and operation of both regenerative type (resonant cavity) and traveling-wave type devices. Experimental results are reported. Gains up to 20 db were achieved with the first type and up to 30 db with the second type.

[26] Bridges, T. J.
A parametric electron beam amplifier.
Proceedings of the IRE, 46(2): 494–495; February, 1958.
An amplifier using an electron beam instead of the ferrites, as proposed by H. Suhl (see [52]), has been built and some experimental results are reported.

[27] Buchmiller, L. D. and Wade, G.
Pumping to extend traveling-wave-tube frequency range.
Proceedings of the IRE, 46(7): 1420–1421; July, 1958.
Points out that the effects noted following the pumping with a high-level signal the frequency range of a commercially available traveling-wave tube may be due, at least in part, to the parametric effects available in beams, or it may be due to mixing effects associated with electron beams.

[28] Clavier, P. A.
Parametric and pseudo-parametric amplifiers.
Proceedings of the IRE, 47(9): 1651; September, 1959.
Develops the theory for a proposed parametric amplifier which would use the transverse oscillations of an electron beam in a time-varied potential-well transverse to the direction of flow. There would be an input and output coupler separated by an interaction.The author declares that the "low-noise electron-beam parametric amplifier" of Adler, Hrbek, and Wade (see [21]) should not be considered a parametric device.

[29] Cook, J. S. and Louisell, W. H.
Fast longitudinal space charge wave parametric amplifiers.
1959 IRE WESCON Convention Record, (pt. 3): 77–85.
First discusses the theory of "active" and "passive" coupling of propagating waves, introducing an "effective coupling" parameter. Principles of traveling-wave parametric amplification are next discussed, followed by a review of problems of fast space charge wave amplifiers and possible solutions.

[30] Electron-beam parametric amplifier.
Wireless World, 64(11): 555–556; November, 1958.
A brief reference to the Zenith Radio Corporation's device.

[31] Fast-wave parametric amplifier.
Electrical Engineering, 77(11): 1071–1072; November, 1958.
Gives a brief description of the operating characteristics of Zenith Radio Corporation's vacuum-tube type parametric amplifier. It has a noise figure of about 1 db and a gain up to 30 db.

[32] Gould, R. W.
Traveling-wave couplers for longitudinal beam-type amplifiers.
Proceedings of the IRE, 47(3): 419–426; March, 1959.

Formulates the expressions governing traveling-wave interaction between an electron beam and a slow-wave circuit. The equations are solved in terms of the mode amplitudes at the output of the traveling-wave coupler and the mode amplitudes at the input. The results are then applied to the design of fast space-charge wave couplers for longitudinal beam type parametric amplifiers.

[33] Haus, H. A.
The kinetic power theorem for parametric, longitudinal, electron-beam amplifiers.
IRE Transactions on Electron Devices, ED-5(4): 225–232; October, 1958.
Develops a generalization of Chu's power theorem, for exploring the limitations on noise performance in such parametric amplifiers. No obstacles appear theoretically to prevent such devices from achieving the ultimate in noise performance.

[34] Louisell, W. H. and Quate, C. F.
Parametric amplification of space charge waves.
Proceedings of the IRE, 46(4): 707–716; April, 1958. (Bell Monograph 3069.)
Description of a "distributed" parametric amplifier using an electron beam and CW source oscillating at twice the signal frequency for power. Discusses both the fast space charge wave and the slow space charge wave.

[35] Louisell, W. H.
A three-frequency electron-beam parametric amplifier and frequency converter.
Journal of Electronics and Control, 6(1): 1–25; January, 1959.
Gives conditions for occurrence of a current modulation threshold which must be exceeded to produce growing waves. The Manley-Rowe relations are verified for the parametric beam, and the gain per unit length is found. Expressions are found for the propagation constants and for boundary conditions.

[36] Someya, I.
Report of advances in microwave theory and techniques in Japan—1958.
IRE Transactions on Microwave Theory and Techniques, MTT-7(3): 331; July, 1959.
Includes one Japanese reference to a parametric amplifier using an electron beam.

[37] Wade, G. and Heffner, H.
Gain, bandwidth and noise in a cavity type parametric amplifier using an electron beam.
Journal of Electronics and Control, 5(6): 497–509; December, 1958.
Shows that in practice it is almost impossible to cancel completely and simultaneously the two uncorrelated noise sources in the electron beam. The requirements for a large beam current and large plasma wavelength lead to minimum noise figures around 3 db. An actual example is worked out in which the gain is about 15 db and the bandwidth 43 kc.

[38] Wade, G. and Adler, R.
A new method for pumping a fast space-charge wave.
Proceedings of the IRE, 47(1): 79–80; January, 1959.
Uses the analogy of a pendulum under the influence of a time-varying force field to illustrate the principle of pumping a fast space-charge wave in an electron beam, in parametric amplification.

Ferrite Types

[39] Amplifier for radio astronomy.
Engineering, 184(4766): 59; July 12, 1957.
A brief description of the Bell Telephone Laboratories ferromagnetic amplifier.

[40] Berk, A. D., Kleinman, L., and Nelson, C. E.
Modified semi-static ferrite amplifier.
1958 IRE WESCON Convention Record, (pt. 3): 9–12.
Describes an operation in which the uniform precession is used as the idling magnetostatic mode. This is compared with a conventional semistatic operation. The theory is checked by an experimental model, and gain was observed in excess of 60 db.

[41] Ferrite microwave amplifier developed.
Electronics, 31(8): 32–33; February 21, 1958.
Brief description of the Bell Telephone Laboratories solid-state microwave amplifier.

[42] Haun, R. D. and Osial, T. A.
Gain measurements on a pulsed ferromagnetic microwave amplifier.
Proceedings of the IRE, 47(4): 586–587; April, 1959.
Amplifier has a flattened coaxial resonant line in a rectangular cavity, using polycrystalline yttrium iron garnet. A chart shows power gain as a function of pump power.

[43] Hogan, C. L., Jepsen, R. L., and Vartanian, P. H.
New type of ferromagnetic amplifier.
Journal of Applied Physics, 29(3): 422–423; March, 1958. (Presented at Conference on Magnetism and Magnetic Materials, held November 18–21, 1957, at Washington, D. C.)
Simple physical explanation of the device proposed by H. Suhl. (See [52].)

[44] Microwave device is ferromagnetic.
Electronics, 30(7B): 26; July 20, 1957.
Brief news item of experimental ferromagnetic amplifier being worked on at the Bell Telephone Laboratories.

[45] Nikolsky, V. V.
On the theory of a microwave ferrite amplifier (In Russian).
Radiotekhnika i Elektronika, 4(4): 726–728; April, 1959.
A theoretical study of the principles of a parametric amplifier of this type.

[46] Poole, K. M. and Tien, P. K.
A ferromagnetic resonance frequency converter.
Proceedings of the IRE, 46(7): 1387–1396; July, 1958.
Based on the amplifier/oscillator proposal of Suhl, the paper discusses a frequency converter which uses a ferromagnetic material in a cavity which supports three resonant modes. Theory and experimental results were found to agree rather closely.

[47] Poole, K. M. and Tien, P. K.
Measurements on active microwave ferrite devices.
1957 IRE WESCON Convention Record, (pt. 3): 170–174.
To provide a check on the theory of microwave amplification or oscillation in a ferromagnetic resonance system as proposed by H. Suhl, a sample version has been constructed and operated with resulting agreement between experiment and theory.

[48] Solid state gains new amplifier.
Electronics, 30(8): 24, 26; August 1, 1957. Also in *Bell Laboratories Record*, 35(8): 316–317; August, 1957.
News item about successful operation of a ferromagnetic amplifier in microwave range by Bell Telephone Laboratories.

[49] Solid-state maser amplifier uses ferrites.
Journal of the Franklin Institute, 264(3): 260–261; September, 1957.
A brief description of the work being done at the Bell Telephone Laboratories on ferromagnetic amplifiers.

[50] Suhl, H.
Ferromagnetic microwave amplifier.
Physics Today, 11(9): 28–30; September, 1958.
Briefly reviews maser-type devices, then gives basic theory for a ferrite-type parametric amplifier. Also cites related work in this field.

[51] Suhl, H.
Origin and use of instabilities in ferromagnetic resonance.
Journal of Applied Physics, 29(3): 416–421; March, 1958.
Presents basic theory of the behavior of ferromagnetic materials with application to ferromagnetic amplifiers.

[52] Suhl, H.
Proposal for a ferromagnetic amplifier in the microwave range.
Physical Review, 106(2): 384–385; April 15, 1957.
Discusses three alternative types of operation (magnetostatic, semistatic, and electromagnetic modes) which may be used in the design of a microwave amplifier. In general, it relies on the modulation of the real part of a susceptibility, rather than on the maser principle of altering normal populations of two levels.

[53] Suhl, H.
Quantum analog of the ferromagnetic microwave amplifier.
Journal of the Physics and Chemistry of Solids, 4(4): 278–282; 1958. (Bell Monograph 2970.)

A quantum mechanical model of a ferromagnetic microwave amplifier has been built to compare modes of operation with a three-level maser. It is found that in a three-level maser it is essential to have a negative temperature for two levels while the analog of the ferromagnetic amplifier depends only on the time-varying part of the density matrix.

[54] Suhl, H.
Theory of a ferromagnetic microwave amplifier.
Journal of Applied Physics, 28(11): 1225–1236; November, 1957. (Bell Monograph 2926.)
Gives a survey of 3 possible types of operation (electromagnetic, semistatic, and magnetostatic) with general theory included. The three types of operation are also defined as: two electromagnetic cavity modes, two sample modes, and lastly, one sample and one cavity mode. An appendix discusses the gain-bandwidth problem.

[55] Tien, P. K. and Suhl, H.
A traveling-wave ferromagnetic amplifier.
Proceedings of the IRE, 46(4): 700–706; April, 1958. (Bell Monograph 3043.)
A proposal for a traveling-wave amplifier consisting of two transmission lines embedded in a ferromagnetic medium.

[56] Weiss, M. T.
Solid-state microwave amplifier and oscillator using ferrite.
Journal of Applied Physics, 29(3): 421; March, 1958. (Presented at Conference on Magnetism and Magnetic Materials, held November 18–21, 1957, in Washington, D. C.)
Brief item on a device built and operated at Bell Telephone Laboratories called the MAVAR (modulating amplifiers, by variable reactance).

[57] Weiss, M. T.
Solid-state microwave amplifier and oscillator using ferrites.
Physical Review, 107(1): 317; July 1, 1957.
A device based on the proposal of H. Suhl (see [52]) has been built and operated. Results of these experiments are given.

[58] Whirry, W. L. and Wang, F. B.
Phase dependence of a ferromagnetic microwave amplifier.
Proceedings of the IRE, 46(9): 1657–1658; September, 1958.
Experimental results using a polycrystalline yttrium garnet in a parametric amplifier are described. Photographs show oscilloscope traces of the phase relationship of output pulses, signal input and pump input.

Diode Types

[59] Bell, C. V. and Wade, G.
Circuit considerations in traveling-wave parametric amplifiers.
1959 IRE WESCON Convention Record, (pt. 2): 75–82.
Discusses the circuits appropriate to the wideband operation of a diode-type traveling-wave amplifier. Presents a Brillouin diagram which allows the computation of conditions for high gain, wideband operation and other characteristics.

[60] Bloom, S. and Chang, K. K. N.
Parametric amplification using low-frequency pumping.
Journal of Applied Physics, 29(3): 594; March, 1958.
Conventional parametric amplifiers use one-pump system. This discusses an amplifier using lower-frequency pumping in which two pumping sources are used.

[61] Bossard, B. B.
Superregenerative reactance amplifier.
Proceedings of the IRE, 47(7): 1269–1271; July, 1959.
A diode-type parametric amplifier having superregeneration is described. Because of the constant threshold value of the oscillations, this type of amplifier could be used as a threshold device or as a limiter.

[62] Brand, F. A., Matthei, W. K., and Saad, T.
The Reactatron—a low-noise semiconductor diode, microwave amplifier.
Proceedings of the IRE, 47(1): 42–44; January, 1959.
Uses only semiconductor diodes for its nonlinear reactance. The two *p-n* junction diodes are in a balanced hybrid system. At a frequency of 2900 mc, power gains in excess of 30 db have been observed, with effective input noise temperatures less than 290°K.

[63] Breitzer, D. I. and Sard, E. W.
Low frequency prototype backward-wave reactance amplifier.
Microwave Journal, 2(8): 34–37; August, 1959.
Presents the theory and experimental results of amplifiers of this type which use matched pairs of diodes. Numerous parameters are described.

[64] Chang, K. K. N.
Analysis of a four-terminal parametric amplifier.
RCA Review, 20(2): 205–221; June, 1959.
Describes an amplifier having three cascaded stages—a converter, an amplifier, and a modulator—using germanium junction diodes. It can be operated at linear gains as high as 30 db, with sensitivity at such gains of 120 dbm or better.

[65] Chang, K. K. N.
Four-terminal parametric amplifier.
Proceedings of the IRE, 47(1): 81–82; January, 1959.
The amplifier uses a lower-frequency pump and has three cascaded stages. It can be operated at linear gains as high as 30 db, with a sensitivity of 120 dbm or better. Noise factors at these gains are around 2.5 db. Germanium junction diodes are used.

[66] Chang, K. K. N.
Harmonic generation with nonlinear reactances.
RCA Review, 19(3): 455–464; September, 1958.
Following the derivation of the theory of frequency multiplication using nonlinear reactances, results of an experiment using a germanium point-contact diode are given. At high input power levels the efficiency drops below the theoretical value.

[67] Chang, K. K. N. and Bloom, S.
A parametric amplifier using lower-frequency pumping.
1958 IRE WESCON Convention Record, (pt. 3): 23–27.
Experimental work using a special zero-biased semiconductor diode is reported. Two cases are described; one with a signal frequency of 380 mc and a pumping frequency of 300 mc, and the other with a signal frequency of 6.6 kmc and a pump frequency of 4 kmc.

[68] DeLoach, C. B. and Sharpless, W. M.
An *X*-band parametric amplifier.
Proceedings of the IRE, 47(9): 1664; September, 1959.
Describes the construction and operation of an amplifier using special point-contact gallium arsenide diodes. It produced a gain of 10 db with a 75-mc bandwidth with 100 mw of pump power.

[69] Diodes for parametric amplifiers.
Electronic Industries, 18(3): 105, 270; March, 1959.
Reports on the operating characteristic of diodes produced by Hughes Aircraft Co. One type operates below 1000 mc and the other type is for the microwave region. Noise temperatures, cutoff frequencies, gain and bandwidth are described.

[70] Endler, H., Berk, A. D., and Whirry, W. L.
Relaxation phenomena in diode parametric amplifiers.
Proceedings of the IRE, 47(8): 1375–1376; August, 1959.
Presents a theory to explain relaxation oscillations observed in *S*-, *C*-, and *X*-band parametric amplifiers using CW pump sources and no other signal inputs.

[71] Englebrecht, R. S.
A low-noise nonlinear reactance traveling wave amplifier.
Proceedings of the IRE, 46(9): 1655; September, 1958.
Gives operating characteristics of an experimental UHF amplifier which uses four diffused-junction silicon diodes having low resistive loss. The noise figure is 3.5 db and the bandwidth 10–20 mc.

[72] Greene, J. C. and Lombardo, P. P.
Low noise 400-mc reactance amplifiers.
Microwave Journal, 2(5): 28–31; May, 1959.
Gives construction details of three types of parametric amplifiers or for three modes of operation; namely, sum-frequency mode, two-port difference-frequency mode, and one-port difference-frequency mode. Varactor diodes developed by Bell Telephone Laboratories are used.

[73] Heffner, H. and Kotzebue, K.
Experimental characteristics of a microwave parametric amplifier using a semiconductor diode.
Proceedings of the IRE, 46(6): 1301; June, 1958.
A report on the characteristics of a microwave parametric amplifier using a back-biased germanium junction diode.

[74] Heffner, H. and Wade, G.
Gain, bandwidth, and noise characteristics of a variable-parameter amplifier.
Journal of Applied Physics, 29(9): 1321–1331; September, 1958.
Discusses the principles of parametric amplifiers, using the two-tank circuit as a model in the analysis. The case of the two-tank circuit for frequency conversion is also included. Noise figures and bandwidth are emphasized throughout. Essentially a revised version of Stanford University Electron Tube Laboratories Technical Report No. 28.

[75] Heffner, H. and Wade, G.
Minimum noise figure of a parametric amplifier.
Journal of Applied Physics, 29(8): 1262; August, 1958.
Gives a noise figure expression suitable for solid-state parametric amplifiers and contrasts it to the expression for beam types where shot-noise terms are important. The minimum noise figure is found to approach the ratio of the pumping frequency to the idling frequency.

[76] Heilmeier, G. H.
An analysis of parametric amplification in periodically loaded transmission lines.
RCA Review, 20(3): 442–454; September, 1959.
Gives the theory of traveling-wave parametric amplifiers. A lossless transmission line periodically loaded with nonlinear capacitance (back-biased semiconductor diodes) is the propagating structure. The gain is shown to be a function of the spacing and static capacitance of diodes, frequencies of operation, and impedance of the unloaded line.

[77] Herrmann, G. F., Uenohara, M., and Uhlir, A., Jr.
Noise figure measurements on two types of variable reactance amplifiers using semiconductor diodes.
Proceedings of the IRE, 46(6): 1301–1303; June, 1958.
Results of experiments on low noise amplification at UHF and microwave frequencies by *p-n* junction diodes.

[78] Hilibrand, J. and Beam, W. R.
Semiconductor diodes in parametric subharmonic oscillators.
RCA Review, 20(2): 229–253; June, 1959.
Discusses factors affecting the performance of diodes in such oscillators, including effects of stray capacitance, spreading resistance, junction conductance, and capacitance-voltage sensitivity. Minimum rise times and minimum quality factors are stated.

[79] Jones, E. M. T. and Honda, J. S.
A low noise up-converter parametric amplifier.
1959 IRE WESCON Convention Record, (pt. 1): 99–107.
After discussing the relation of gain and noise figures to the diode loss, available capacitance variation and generator and load terminations, the paper describes the construction of an experimental up-converter which uses a back-biased diffused-junction diode. Gains ranged from 12.4 to about 20 db, with noise figures of about 1.0 db.

[80] Kibler, L. U.
Directional bridge parametric amplifier.
Proceedings of the IRE, 47(4): 583–584; April, 1959.
Gives expressions for the noise figure of a bridge using varactor diodes. Gains up to 25 db were obtained at 530 mc, with the pump frequency 1060 mc. The average of the noise figures was 3.8 db when operating with a 10-db gain and a bandwidth of about 0.6 mc. The device can also be used as a tunable amplifier.

[81] Kim, C. S.
Four-terminal equivalent circuits of parametric diodes.
1959 IRE WESCON Convention Record, (pt. 2): 91–101.
Derives expressions for four-terminal equivalent circuits, including three frequencies, for converters and for amplifiers. These circuits may be used to obtain expressions for gain, bandwidth, and noise figure.

[82] Knechtli, R. C. and Weglein, R. D.
Low noise parametric amplifier.
Proceedings of the IRE, 47(4): 584–585; April, 1959.
Describes operation of an amplifier using gold-bonded diodes. By cooling with liquid nitrogen the minimum amplifier noise temperature was reduced to 50° K. Operation was in the *S* band.

[83] Leenov, D.
Gain and noise figure of a variable-capacitance up-converter.
Bell System Technical Journal, 37(pt. 4): 989–1008; July, 1958.
Discusses the theory of the performance of a *p-n* junction nonlinear-capacitance diode used as a low-noise amplifying frequency converter in a case in which the output-signal frequency is many times larger than the frequency of the input signal. Gives formulas for maximum gain and for noise figures.

[84] Lombardo, P. P. and Sard, E. W.
Low-frequency prototype traveling-wave reactance amplifier.
Proceedings of the IRE, 47(5): 995–996; May, 1959.
A junction-diode type amplifier, using commercial diodes, is described and experimental results are given. Frequency responses, power gains and noise are among points covered.

[85] Lombardo, P. P. and Sard, E. W.
Low noise microwave reactance amplifiers with large gain-bandwidth products.
1959 IRE WESCON Convention Record, (pt. 1): 83–98.
Describes the operation of several low-frequency devices using silicon diodes, including amplifiers, up-converters, and demodulators. Both one-part and two-part operation are considered.

[86] Low-noise amplifier for high frequencies uses new semi-conductor diodes.
Bell Laboratories Record, 36(7): 250–251; July, 1958.
Experimental devices, one of a family of parametric amplifiers being developed by Bell Telephone Laboratories, shows great promise and improvement over many types of microwave receivers. It has low noise, greater bandwidth, and operates at ordinary temperatures.

[87] Low-noise amplifier using semiconductor diodes.
Electronics and Radio Engineer, 35(7): 267; July, 1958. Also in *Journal of the Franklin Institute*, 266(2): 151–152; August, 1958.
Brief description of features of the Bell Telephone Laboratories' parametric amplifiers, including a traveling-wave amplifier configuration which uses arrays of several diodes and has a bandwidth of 100 mc at a 400-mc signal frequency and a pump frequency of 900 mc.

[88] Microwave amplifiers may improve radar.
Machine Design, 30(12): 14; June 12, 1958.
Brief descripiton of a germanium diode type parametric amplifier developed by RCA Laboratories. It has been tested in the UHF and 6000-mc regions.

[89] Nergaard, L. S.
Nonlinear-capacitance amplifiers.
RCA Review, 20(1): 3–17; March, 1959.
After briefly reviewing the development of parametric amplifiers, the paper discusses gain mechanism in nonlinear capacitance, diode capacitor amplifiers, and performance characteristics of various types.

[90] Oguchi, B., Kita, S., Inage, N., and Okajima, T.
Microwave parametric amplifier by means of germanium diode.
Proceedings of the IRE, 47(1): 77–78; January, 1959.
Describes operation of two types of diodes—one, a gold-bonded type, and the other, a silver-bonded type, the latter proving to be superior. A gain of 15–20 db is obtained when the pump frequency is 8100 mc, and a bandwidth of 15–25 mc is observed.

[91] Olson, F. A., Wang, C. P., and Wade, G.
Parametric devices tested for phase-distortionless limiting.
Proceedings of the IRE, 47(4): 587–588; April, 1959.
Gives results of tests on two diode-type parametric devices, one being an amplifier and the other a frequency converter. Expressions are given to describe the operation of each.

[92] Parametric amplifier ups scatter range.
Electronics, 31(45): 96; November 7, 1958.
Brief description of a diode-type parametric amplifier developed by ITT Laboratories for use in a 90-mile scatter propagation link. The range is expected to be extended to more than 350 miles under favorable conditions.

[93] Petrack, P.
Predicts boom for new diode.
Electronics, 32(15): 26; April 10, 1959.
Predicts the sales potential for parametric amplifier diodes, as seen by ITT Components Division managers. The price outlook by 1962 for such diodes is also given.

[94] Pittman, W. C.
A parametric amplifier in space-probe tracking.
Astronautics, 4(8): 40, 44; August, 1959.
Gives design and operational characteristics of a silicon-diode-type parametric amplifier developed by ITT Laboratories for use in the Army Ballistic Missile Agency tracking station. It allowed tracking of the Pioneer IV satellite to a distance of 200,000 miles on radiated power of 180 mw. It had a noise figure of about 1 db compared to 7.5 db for electron-tube amplifiers.

[95] Reed, E. D.
The variable capacitance parametric amplifier.
IRE Transactions on Electron Devices, ED-6(2): 216–224; April, 1959.
Reviews operation of diode-type devices, and compares noise performance with vacuum-type amplifiers. Written for the nonspecialist.

[96] Salzberg, B. and Sard, E. W.
Low-noise wide-band reactance amplifier.
Proceedings of the IRE, 46(6): 1303; June, 1958.
Summary of a study of a reactance amplifier operated in a sum-frequency mode indicating that very-low effective input-noise temperatures are possible.

[97] Seidel, H. and Herrmann, G. E.
Circuit aspects of parametric amplifiers.
1959 IRE WESCON Convention Record, (pt. 2): 83–90.
Discusses two cases. In the first, there is only the signal frequency and a lower sideband, as in a lower-sideband amplifier. The second case considers a periodic cascade in which the pump phase varies uniformly.

[98] Sie, J. and Weisbaum, S.
Noise figure of receiver systems using parametric amplifiers.
1959 IRE National Convention Record, (pt. 3): 141–157.
Shows that a parametric amplifier used in one of the following three systems can have an over-all-system noise figure of 1 db: 1) circulator couplet (needs only one amplifier); 2) hybrid couplet (needs two amplifiers, no frequency limitation); 3) up-converter (no frequency limitation).

[99] Siegman, A. E.
Phase-distortion loss limiting by a parametric method.
Proceedings of the IRE, 47(3). 447–448; March, 1959.
Presents the theory of using parametric amplifiers as limiters, with limiting taking place at the threshold point.

[100] Shunaman, F.
The variable reactance amplifier.
Radio Electronics, 30(2): Cover, 78–80, 82; February, 1959.
Describes in simplified terms the operation of parametric amplifiers of the diode type. Illustrates an amplifier, developed by ITT Laboratories, designed to operate at 900 mc.

[101] Sterzer, F.
Microwave parametric subharmonic oscillators for digital computing.
Proceedings of the IRE, 47(8): 1317–1324; August, 1959.
Describes a variable-capacitance diode-type subharmonic oscillator having an output frequency of 2000 mc. Pulse-repetition rates of a few hundred megacycles are possible. Applications are discussed for amplifying, scaling and logic functions.

[102] Stevens, K. W. H.
Circuit analogues of Suhl-type masers.
Journal of Electronics and Control, 4(3): 275–279; March, 1958.
Discusses the theory of operation of two tuned circuits, which use the varying of inductances with time, thereby obtaining amplification under certain conditions. Provides a basis for the theory of parametric amplifiers.

[103] Torrey, H. C. and Whitmer, C. A.
Crystal Rectifiers.
McGraw-Hill Book Co., Inc., New York, N. Y., 443 pp.; 1948. (M.I.T. Radiation Lab. Series, vol. 15).
Develops the theory of reactance-variation amplification in a form similar to recent theory, and applies the theory to explain their observations of negative conductances in crystal-diode mixers.

[104] Uhlir, A., Jr.
Junction diode amplifiers.
Scientific American, 200(6): 118–120, 123, 124, 126, 127, 129; June, 1959.
Describes the basic principles of parametric diode-type devices, with particular emphasis on the theory and functions of diodes. Recent experimental work is summarized and future applications are mentioned.

[105] Uhlir, A., Jr.
Junction diodes in microwave circuits.
Proceedings of the Institution of Electrical Engineers, 105B (Supplement 11): 661, 672, 673; May, 1958.
Gives only an abstract. States conditions under which diodes can serve as amplifiers, as well as giving suitable diode materials.

[106] Uhlir, A., Jr
The potential of semiconductor diodes in high-frequency communications
Proceedings of the IRE, 46(6): 1099–1115; June, 1958.
Describes the function of solid-state diodes in parametric amplifiers and nonlinear frequency converters, as well as related uses. Design data are included with basic theory.

[107] Uhlir, A., Jr.
Shot noise in *p-n* junction frequency converters.
Bell System Technical Journal, 37(4): 951–988; July, 1958.
Suggests structures for approaching the ideal of theoretically noiseless amplification possible with a *p-n* junction, having a purely capacitive nonlinear admittance. Experiments with a diffused silicon junction diode are reported. Discusses the low-noise frequency conversion possible with a nonlinear resistance diode used in conjunction with pulsed local-oscillator currents.

[108] Van der Ziel, A.
On the mixing properties of nonlinear capacitances.
Journal of Applied Physics, 19(11): 999–1006; November, 1948.
Concludes that a variable-reactance amplifier should exhibit very low noise, because of the absence, ideally, of Nyquist-Johnson noise.

[109] Wade, G. and Heffner, H.
Microwave parametric amplifiers and converters.
Proceedings of the Institution of Electrical Engineers, 105B (supplement 11): 667–679; May, 1958.
Develops expressions for the noise figures and bandwidth for parametric devices.

[110] Warren, T. B.
Low-noise parametric amplifiers and converters.
1959 IRE National Convention Record, (pt. 3): 158.
Compares experimental results with theoretical values for various types of variable-capacitance devices as to noise figures, stability and bandwidth, in the 500 to 2000-mc range. Other topics are: fabrication of diffused junction silicon diodes, a system designed to minimize effects of input loading variations, and a stable low-frequency source which produces high-frequency local oscillator power.

[111] Younger, J. J., Little, A. G., Heffner, H., and Wade, G.
Parametric amplifiers as superregenerative detectors.
Proceedings of the IRE, 47(7): 1271–1272; July, 1959.
Discusses the superregenerative operation of cavity-type parametric amplifiers which use semiconductor diodes. Discusses some of the effects which play a part in the self-quenching process.

[112] Younger, J. J., Little, A. G., Heffner, H., and Wade, G.
Superregenerative operation of parametric amplifiers.
1959 IRE WESCON Convention Record, (pt. 1): 108–111.
Reports on the operation of several diode type cavity amplifiers as both self-quenched and separately-quenched superregenerative devices. In self-quenched superregenerative operation, gains as high as 87 db were observed, compared to 20 db under normal operation. Greatly increased bandwidths and stability were observed without sacrifice in noise figures.

Parametron Types

[113] Fukui, K., Unose, K., Habara, K., and Kato, M.
Multi-apertured parametrons (In Japanese).
Journal of the Institute of Electrical Communication Engineers of Japan, 41(2): 147–151; February, 1958.
In order to avoid the construction difficulties involved in the small cores used in conventional parametrons, multi-apertured parametrons have been developed having good

operating characteristics and greater ease of manufacture. Design details are given.

[114] Goto, E.
On the application of parametrically excited nonlinear resonators (In Japanese).
Journal of the Institute of Electrical Communication Engineers of Japan, 38(10): 770–775; October, 1955.
Shows that oscillations of such resonators can be expressed by a modified form of Mathieu's equation, with a term included to take care of nonlinearity. If parametric excitation is interrupted properly, the reservators are capable of storing binary information with the binary state controlled by means of small signals.

[115] Goto, E.
The parametron, a digital computing element which utilizes parametric oscillation.
Proceedings of the IRE, 47(8): 1304–1316; August, 1959.
This element consists of a resonant circuit having a nonlinear reactive element (ferrite-core coils) oscillating at one-half the driving frequency. The choice of two stationary phases, π radians apart, is used to represent a binary digit. Circuit design and applications are discussed.

[116] Hanawa, K. and Kusunoki, K.
Signal converter by magnetic cores for parametron-device (In English).
Electrical Communication Laboratory Reports, Nippon Telegraph & Telephone Public Corporation, 7(2): 25–31; February, 1959.
Discusses core construction and design. Describes a method of converting signals such as from telephone subscribers' lines to parametron signals, using the cores in a matrix arrangement.

[117] Kamata, K. and Sasaki, F.
Parametron and punched card recorder for standard meson monitor.
Journal of the Scientific Research Institute of Japan, 51: 54; 1957.
Abstract unavailable.

[118] Muroga, S.
Elementary principle of parametron and its application to digital computers.
Research and Engineering, the Magazine of Datamation, 4(5): 31–34; September–October, 1958.
After reviewing the basic principles of parametrons, the use of such devices in a program-stored binary computer, having fixed point in a parallel system, is discussed. Speed of operation is almost comparable to electron tube types, and maintenance time is negligible.

[119] Muroga, S. and Takasima, K.
System and logical design of the parametron computer MUSASINO-1 (In Japanese).
Journal of the Institute of Electrical Communication Engineers of Japan, 41(11): 1132; November, 1958.
Abstract not available.

[120] Nakagome, Y., Kamibayashi, T., and Wada, T.
Parametron Morse to five-unit converter (In Japanese).
Journal of the Institute of Electrical Communication Engineers of Japan, 40(9): 974–980; September, 1957.
Parametrons are used in this automatic code-converter. Experimental results are given as well as a description of its components and circuits.

[121] Nishiguchi, K.
The misoperation of parametron due to the hysteresis of parametron core (In Japanese).
Journal of the Institute of Electrical Communication Engineers of Japan, 42(2): 151–155; February, 1959.
A signal considerably larger than expected is required in order to overcome the Barkhausen noise. If the control signal is smaller than the read-out signal, the memory of the parametron core which has memorized the phase of the last oscillation is read out, causing a misoperation.

[122] Oshima, S., Enomoto, H., and Watanabe, S.
Analysis of parametrically excited circuits—parametron and magnetic amplifier (In Japanese).
Journal of the Institute of Electrical Communication Engineers of Japan, 41(10): 971–978; October, 1958.
Analysis is done by means of conversion matrices in the frequency domain. The parametron is used as an example of a parametrically-excited two-terminal network. The calculated oscillation condition agrees with experimental results.

[123] Oshima, S., Nakagome, Y., and Inohama, R.
Signal input and output circuits for parametron using transistors and their applications (In Japanese).
Journal of the Institute of Electrical Communication Engineers of Japan, 41(9): 856–861; September, 1958.
Gives circuit designs for signal input and output circuits utilizing parametrons and transistors and describes their application to analog-digital converters, digital-analog converters, and parametron circuit testers.

[124] Paramistors and computer costs.
Electronic Design, 7(17): 42; August 19, 1959.
A description of their principles of operation and uses, including photographs and a circuit diagram. The cost of a computer using such devices is estimated to be one tenth that of one using semiconductors and cores.

[125] Terada, H.
Parametron; an amplifying logic element.
Control Engineering, 6(4): 110–115; April, 1959.
Reviews principles of operation, then discusses possible applications, which include logical computing circuits and memory circuits. Speed limitations, imposed by its high-frequency power requirements, constitute the main disadvantage of such devices.

[126] Zeniti, K., Katsunuma, S., Hanawa, K., Ikeno, N., and Fukuoka, T.
An experimental crossbar telephone exchange system using parametrons (In Japanese).
Journal of the Institute of Electrical Communication Engineers of Japan, 42(3): 225–231; March, 1959.
Describes the operation of an experimental one-hundred-line capacity exchange using about 900 parametrons. After a test of one year, the operation has been good in regard to reliability, compactness, cost, power consumption, etc.

[127] Zeniti, K., Husimi, K., Hiyama, Y., and Yamanaka, K.
Parametric excitation using selenium rectifier (In Japanese).
Journal of the Institute of Electrical Communication Engineers of Japan, 41(8): 786–791; August, 1958.
Further improvement is necessary for a parametron using a selenium rectifier to achieve faster operating speed and lower power consumption. However, it is satisfactory at low frequencies, uses the same power as a ferrite parametron, and has a capacity-variation rate nearly the same as a germanium junction diode.

[128] Zeniti, K., Sekiguti, S., and Takasima, M.
Parametric excitation using variable capacitance of ferroelectric materials (In Japanese).
Journal of the Institute of Electrical Communication Engineers of Japan, 41(3): 239–244; March, 1958.
Discusses the use of ferroelectric materials such as barium titanate ceramics in parametron devices. Describes the parametric-excitation ratio, selectivity, power consumption and temperature coefficient.

[129] Zeniti, K.
Parametron (In Japanese).
Journal of the Institute of Electrical Communication Engineers of Japan, 41(4) · 397–403; April, 1958.
Describes and illustrates the design of parametrons—one of a collection of papers on new components and materials.

[130] Zeniti, K. and Nisiguti, K.
Reading of recorded signals with a low frequency parametron (In English).
Electrical Communication Laboratory Reports, Nippon Telegraph & Telephone Public Corporation, 7(2): 48–53; February, 1959.
Gives a full description of the equipment and operation of the system. In order to increase the memory capacity of the system, various methods of multiplexing, especially time division multiplexing, must be used.

Miscellaneous Items

[131] Bloom, S. and Chang, K. K. N.
Theory of parametric amplification using nonlinear reactances.

RCA Review, 18(4): 578–593; December, 1957.
An analysis of the parametric amplifier in terms of an equivalent circuit using a nonlinear inductance in general enough terms to describe not only linear but nonlinear amplification.

[132] Cassedy, E. S., Jr.
A surface wave parametric amplifier.
PROCEEDINGS OF THE IRE, 47(8): 1374–1375; August, 1959.
Uses a slab of ferroelectric material to replace the usual dielectric slab, in order to operate at millimeter wavelengths. Theory and operation are described.

[133] Chang, K. K. N. and Bloom, S.
Parametric amplifier using lower-frequency pumping.
PROCEEDINGS OF THE IRE, 46(7): 1383–1386; July, 1958.
Using a nickel-manganese ferrite core, a nonlinear inductance type parametric amplifier gave a 30 per cent power gain at a signal frequency of 10 mc and a pump frequency of 7 mc. A nonlinear capacitance device using a germanium reversed-bias junction diode achieved a stable net gain of 35 db at 380 mc, having a pumping circuit at 300 mc.

[134] Chang, K. K. N. and Bloom, S.
A parametric amplifier using lower-frequency pumping.
Proceedings of the Institution of Electrical Engineers, 105B (supplement 11): 680–683; May, 1958.
Describes experiments using first a nickel-manganese ferrite, with a small amount of power gain. Using a germanium junction diode in a second experiment gave much a better result, with a 35-db gain obtained.

[135] Cohn, S. B.
The noise figure muddle.
Microwave Journal, 2(3): 7, 9, 11; March, 1959.
Points out some of the errors in the common concepts of measurements of noise figures. Discrepancies occur in the measuring of nonlinear networks such as mixers or parametric amplifiers, depending on the use of the noise-source method or the signal-generator method. Proper methods are prescribed.

[136] Coleman, P. D. and Becker, R. C.
Present state of the millimeter wave generation and technique art—1958.
IRE TRANSACTIONS ON MICROWAVE THEORY AND TECHNIQUES, MTT-7(1): 42–61; January, 1959.
Briefly reviews parametric devices and cites six references representative of major developments.

[137] Cullen, A. L.
A travelling-wave parametric amplifier.
Nature, 181(4605): 332; February 1, 1958.
Gives expressions for the theoretical amplification possible with a traveling-wave type of parametric amplifier. Requirements for meeting these ideal conditions are briefly mentioned.

[138] Danielson, W. E.
Low noise in solid state parametric amplifiers at microwave frequencies.
Journal of Applied Physics, 30(1): 8–15; January, 1959.
Uses simple low-frequency network electrical circuits and their mechanical analogs to explain the principles of parametric amplifications; discusses major noise sources; and gives experimental data on four different types of amplifiers (three using semiconductor diodes and one using ferrites).

[139] Edwards, C. F.
Frequency conversion by means of a nonlinear admittance.
Bell System Technical Journal, 35(6): 1403–1416; November, 1956.
Presents the mathematical analysis of a heterodyne conversion transducer having the nonlinear element made up of a nonlinear resistor and a nonlinear capacitor in parallel. Points out nonlinear capacitor is the preferred element for modulators and a nonlinear resistor alone is preferred for converters.

[140] Hartley, R. V. L.
Oscillations in systems with nonlinear reactance.
Bell System Technical Journal, 15(3): 424–440: July, 1936.
Studies the properties of a theoretical capacitor having one plate free to vibrate, which is in a circuit containing a generator operating at a frequency higher than the resonant frequency of the plate. Conditions for oscillation are discussed, including conditions for the required generator voltage. Other applications are discussed.

[141] Haus, H. A.
Power flow relations in nonlinear media.
IRE TRANSACTIONS ON MICROWAVE THEORY AND TECHNIQUES, MTT-6(3): 317–324; July, 1958.
Following the generalizations for nonlinear anisotropic media, and the extension to gyromagnetic media under small-signal excitation at the signal frequency, the author shows under what conditions power gain can be achieved with a three-frequency and a four-frequency excitation of a ferrite. The Manley-Rowe relations (see [144]) are shown to be concerned with coupling coefficients in the operation of a ferrite amplifier.

[142] Kurokawa, K. and Hamasaki, J.
Mode theory of lossless periodically distributed parametric amplifiers.
IRE TRANSACTIONS ON MICROWAVE THEORY AND TECHNIQUES, MTT-7(3); 360–365; July, 1959.
Introduces an operator useful in analyzing the periodically distributed parametric amplifier. Also, develops an expression for the power gain of the amplifier as an application of the theory.

[143] Manley, J. M. and Peterson, E.
Negative resistance effects in saturable reactor circuits.
Transactions of the American Institute of Electrical Engineers, 65: 870–881; 1946.
Analyzes sustained oscillators exhibiting many of the properties of free oscillations, as found in saturable reactor circuitry using the work of R. V. L. Hartley (1917). The analysis of the development of negative resistance is expressed simply, and applied to the three classes of oscillations. Experiment data agree with theory.

[144] Manley, J. M. and Rowe, H. E.
Some general properties of nonlinear elements—part I, general energy relations.
PROCEEDINGS OF THE IRE, 44(7): 904–913; July, 1956.
Derives two independent equations relating the average powers (at different frequencies) in nonlinear inductors and capacitors. The equations are independent of external circuits to which the nonlinear reactor is connected and of the power levels at the various frequencies. These lead to an analysis of gain and stability of nonlinear reactor modulators and demodulators. Special cases are also considered.

[145] Page, C. H.
Frequency conversion with nonlinear reactances.
Journal of Research of the National Bureau of Standards, 58(5): 227–236; May, 1957.
Develops expressions to show that a lossless nonlinear impedance subject to an almost periodic voltage will absorb power at certain frequencies and supply power at other frequencies. Simple cubic capacitors are found to be sufficient for producing any possible conservative modulation or distortion process.

[146] Pierce, J. R.
Use of the principle of conservation of energy and momentum in connection with the operation of wave-type parametric amplifiers.
Journal of Applied Physics, 30(9): 1341–1346; September, 1959.
A theoretical discussion based on the terms of the force exerted by traveling-wave discontinuities or reflecting elements on the waves present in wave-type parametric amplifiers. Proposes that for a guided wave the momentum per unit distance is the power divided by the product of the group and phase velocities.

[147] Roe, G. M. and Boyd, M. R.
Parametric energy conversion in distributed systems.
PROCEEDINGS OF THE IRE, 47(7): 1213–1218; July, 1959.
Discusses the theory of operation of traveling-wave type parametric devices having little or no dispersion. Indicates that pumping will not result in exponential gain of a signal but rather in a conversion of energy to a multiplicity of cross-product frequencies. Discusses two physical models and also the special case of zero dispersion. Use of such systems as frequency converters is pointed out.

[148] Rowe, H. E.

Some general properties of nonlinear elements—part II, small signal theory.
PROCEEDINGS OF THE IRE, 46(5, pt. 1): 850–860; May, 1958.
Uses the small-signal analysis to study the simplest types of nonlinear capacitor modulators, demodulators and negative-conductance amplifiers. The results give the gain, bandwidth, terminal admittances, and sensitivity of these devices, and show the way in which nonlinearity affects these quantities. In general, the bandwidth of the devices approaches zero as nonlinearity approaches zero.

[149] Saito, S.
Parametric amplification of space-charge waves on a thin electron beam (In Japanese).
Journal of the Institute of Electrical Communication Engineers of Japan, 41(11): 1113–1120; November, 1958.
Discusses the more general cases, assuring a thin longitudinal beam with the modulation large compared to the signal, yet small enough to be general by linear theory. Both the inverting and the noninverting cases are treated.

[150] Tannenwald, P. E.
Properties of thin magnetic films for microwave applications.
1959 IRE WESCON CONVENTION RECORD, (pt. 1): 134–141.
Compares properties of the magnetic films with ferromagnetic insulators. In particular, compares frequency response, electromagnetic wave transmission, relation of thin depth to spin numbers, permeability at microwave frequencies and also a scheme representing a spin parametric amplifier.

[151] Tien, P. K.
Parametric amplification and frequency mixing in propagating circuits.
Journal of Applied Physics, 29(9): 1347–1357; September, 1958.
Develops expressions for the properties of a time-varying reactance in propagating structures, including the case in which parametric amplification is possible, as well as cases for frequency conversion, frequency channel selection, both wide- and narrow-band amplifiers, oscillators and backward-wave devices. Noise figures are also considered.

[152] Valdes, L. B.
Circuit conditions for parametric amplification.
Journal of Electronics and Control, 5(2): 129–141; August, 1958.
Signals in a passive-element circuit can be amplified if there is a nonlinear or time-varying reactance. Paper describes the physical model and the circuit conditions necessary for operation and discusses the difference between parametric amplifiers and mixers or modulators.

[153] Van der Ziel, A.
Noise figure of reactance converters and parametric amplifiers.
Journal of Applied Physics, 30(9): 1449; September, 1959.
Derives the noise figure in a simple fashion, and points out its variation from a formula given by Hoffman and Wade (see [74]).

III. MASERS

Review Articles

[154] Ancillary equipment: masers.
Civil Aviation Radio News, (28): 65–68; July, 1958.
History and descriptions of the ammonia and solid-state masers. Includes also information about current developments being made by various groups in England, Canada, and the U.S.A.

[155] Birnbaum, G.
Microwave atomic amplifiers and oscillators.
1957 IRE WESCON CONVENTION RECORD, (pt. 3): 169.
Reviews developments in the field. Also, gives an explanation of the operations of various devices characterized by a method of obtaining the emissive condition: electrostatic focusing in the ammonia beam maser; optical pumping of rubidium vapor; and microwave pulsing and saturating of paramagnetic solid-state systems.

[156] Cade, C. M.
The maser: a new form of microwave oscillator.
Journal of the Television Society, 8(12). 509–511; October–December, 1958.
Gives a short review of the operational principles of solid-state masers and molecular-beam masers.

[157] Combrisson, J. and Townes, C. H.
Production and amplification of microwaves by atomic processes (In French).
Onde Electrique, 36(356): 989–991; November, 1956.
Brief review describing the principles of the maser, the work being done on the ammonia maser at Columbia University, and the possibility of a solid-state version.

[158] Culver, W. H.
Maser; a molecular amplifier for microwave radiation.
Science, 126(3278): 810–814; October 25, 1957.
A general review of the principles and operations of both gaseous and solid-state masers.

[159] Gordon, J. P.
The maser.
Scientific American, 199(6): 42–50; December, 1958.
Reviews the theory and operation of solid-state and gaseous masers. It is well illustrated and is written for the layman.

[160] Gordon, J. P.
A molecular microwave spectrometer, oscillator and amplifier.
IRE TRANSACTIONS ON INSTRUMENTATION, PGI-4: 155–159; October, 1955.
A survey of the principles of a microwave spectrometer and oscillator operating on emission of energy from molecules.

[161] Goudet, G.
The production and amplification of radio oscillations using molecular or atomic transitions (In French).
Onde Electrique, 38(379): 671–686; October, 1958.
Following a discussion of the quantum mechanical principles governing molecular and atomic transitions, the author describes their application to masers and frequency standards of the solid state and of gaseous states. Optical pumping is also described.

[162] Heineken, F. W.
De "maser."
Nederlands Tijdschrift voor Naturkunde, 23(6): 164–167; 1957.
Abstract unavailable.

[163] Klinger, H. H.
Molekulare Mikrowellen-Verstarker (maser) (In German).
Elektronische Rundschau, 12(7): 237–239; July, 1958.
Survey of the electronics of the maser, presenting several basic statements on physical principles. Discusses molecular radiation, negative temperature, light quantum and crystal-type masers, and shows possible applications.

[164] Kontorovich, V. M. and Prokhorov, A. M.
Nonlinear effects of the interaction of resonance fields in the molecular generator and amplifier (In English).
Soviet Physics JETP, 33: 1100–1102; June, 1958. Also in *Zhurnal Eksperimentalnoi i Teoreticheskoi Fiziki*, 33(6): 1428–1430; December, 1957 (In Russian).
An analysis of the polarizability of a quantum system situated in two resonance fields with an auxiliary field. Gives expressions for the possible frequencies of generation and amplification.

[165] Lequeux, J.
Une revolution dans le domaine des hyperfrequencies: Le "maser" oscillateur et amplification moleculaire (In French).
La Nature, (3272): 470–475; 1957.
Abstract unavailable.

[166] Likel, H.
The Maser: a low-noise microwave amplifier.
Western Union Technical Review, 13(3): 99–100; July, 1959.
Gives a brief review of the basic principles of the operation of masers.

[167] Marsh, J. A.
Survey of communications problems associated with space travel.
In: Vistas in Astronautics, Alperin, Morton, Ed.
Pergamon Press, Inc., New York, N. Y., 330 pp.; 1958.
Pages 85–87 point out the potential use of maser amplifiers in space ships to base communication lines.

[168] Maser R and D activity now is widespread.
Electronic News, 3(107): 4, 5; September, 22 1958.
A review of the programs, projects, and progress on masers. Includes list of companies, type of maser, frequency bands and/or wavelengths, and materials being used.

[169] Shimoda, K., Wang, T. C., and Townes, C. H.

Further aspects of the theory of the maser.
Physical Review, 102(5): 1308–1321; June 1, 1956.
A more detailed analysis of certain aspects of theory of the maser is given. In particular effects of saturation and of the resonant cavity design are discussed. Various types of noise and frequency shifts of oscillators are examined.

[170] Shunaman, F.
Revolutionary new oscillator-amplifier.
Radio-Electronics, 26(6): 55–57; June, 1955.
A popular, simplified description of a new device—the maser.

[171] Singer, J. R.
Masers.
John Wiley and Sons, Inc., New York, N. Y., 147 pp.; 1959.
Treats both solid-state and gaseous masers.

[172] Souped-up energy at work: meet the maser.
Product Engineering, 29(2): 10; January 13, 1958.
A few brief paragraphs describing gaseous and solid-state masers.

[173] Townes, C. H.
Masers.
Journal of Applied Physics, 29(3): 238; March, 1958.
Gives an abstract of a review paper on the properties and characteristics of all types of masers.

[174] Townes, C. H. and Schawlow, A.
Microwave Spectroscopy.
McGraw-Hill Book Co., Inc., New York, N. Y., 698 pp.; 1955.
Description of a device used as a high-resolution spectrometer (the maser) is given on pp. 432–434. Information on the molecular-beam maser is given on pp. 482 and 485.

[175] Townes, C. H.
A molecular microwave amplifier, oscillator and frequency standard.
1955 IRE Convention Record, (pt. 10): 180.
Indications from the tests and analysis of data show that the maser should provide an excellent frequency standard. An abstract of the paper is all that appears.

[176] Weber, J.
Amplification of microwave radiation by substances not in thermal equilibrium.
IRE Transactions on Electron Devices, ED-3(1): 1–4; June, 1953.
Paper based on a presentation made at the IRE Electron Tube Conference in Ottawa, in June, 1952. Gives some of the basic theory and methods for obtaining microwave radiation from crystals and gases.

[177] Weibel, G. E.
Masers and related quantum-mechanical devices. Part I.
Sylvania Technologist, 10(4): 90–97; October, 1957.
Reviews basic principles: discusses relation to maser operation of quantum-mechanical behavior of single atoms, energy level of isolated microsystems, interaction with electromagnetic field, energy storage and conversion, and, finally, statistical properties of large assemblies.

[178] Weibel, G. E.
Masers and related quantum-mechanical devices. Part II.
Sylvania Technologist, 11(1)· 26–43; January, 1958.
This part consists of a brief review of quantum mechanics fundamentals and of the derivation of the theory of microwave interaction with a two-level system.

[179] Wittke, J. P.
Molecular amplification and generation of microwaves.
Proceedings of the IRE, 45(3): 291–316; March, 1957.
Reviews the wide variety of devices using molecular systems, including molecular-beam masers, "optically-pumped" amplifiers, etc. Discusses properties such as gain, bandwidth, noise figures. A supplementary note by the author appears in Proceedings of the IRE, 45(7): 1100; March, 1957.

[180] Wolf, H. C.
The molecular amplifier (In German).
Zeitschrift für Angewandte Physik, 10(10): 480–488; October, 1958.
Reviews the operation of solid-state and ammonia masers.

Oscillators

[181] Allais, E.
Study of the dynamic high-field polarization and the construction of an auto-oscillator of the maser type (In French).
Comptes Rendus de l'Academie des Sciences (Paris), 246(26): 3608–3610; June 30, 1958.
Shows that a nuclear resonance line can be inverted by interaction with the paramagnetic saturated resonance levels of a free radical. An 8-watt magnetron is used to saturate the paramagnetic resonance line. A Q meter is used to detect the oscillation output which is at the proton Larmor-frequency.

[182] Basov, N. G. and Prokhorov, A. M.
Application of molecular beams to radiospectroscopic study of rotation spectra of molecules (In Russian).
Zhurnal Eksperimentalnoi i Teoreticheskoi Fiziki, 27(10): 431–438; October, 1954.
Narrow spectral lines (width about 7 kc) and rotation spectra of materials in solid state may be obtained by using molecular beams. A theoretical study of rotation transition in CsF molecules at a frequency of 17.7 kmc using a spectroscope with a waveguide absorption cell and using, also, a cavity-resonator instrument.

[183] Basov, N. G., Veselago, V. G., and Zhabatinski, M. E.
Increasing the Q factor of the cavity resonator by regeneration (In English).
Soviet Physics JETP, 28: 177–178; July, 1955. Also in *Zhurnal Eksperimentalnoi i Teoreticheskoi Fiziki*, 28(2): 242; February, 1955 (In Russian).
An article on the use of cavity resonator with molecular-beam oscillator, resulting in a Q factor of 5×10^6 for periods of up to 20 minutes.

[184] Basov, N. G.
Molecular-beam oscillator (In Russian).
Radiotekhnika i Elektronika, 1(6): 752–757; June, 1956.
Description of a 23,870-mc NH_3 beam oscillator.

[185] Basov, N. G. and Prokhorov, A. M.
Molecular generator and amplifier (In Russian).
Uspekhi Fiziki Nauk, 57: 485–501; 1955.
Applications are mentioned, such as time standards, spectroscopy, etc.

[186] Basov, N. G.
Molecular generator on a beam of ammonia molecules (part I). Study of the operation of a molecular generator (part II) (In Russian).
Pribory i Tekhnika Eksperimenta, (1): 71–77, 77–82; 1957.
Abstract unavailable.

[187] Basov, N. G.
On the condition of self-excitation of free-space molecular oscillators (In English).
Radio Engineering and Electronics, 3(2): 427–429; 1958. Also in *Radiotekhnika i Elektronika*, 3(2): 297–298; February, 1958 (In Russian).
Considers the problem of molecular oscillations in free space, in view of its application to obtaining molecular oscillators and amplifiers for millimetric and submillimetric waves. Examples are given for oscillators employing either ammonia beams or paramagnetic crystals.

[188] Basov, N. G. and Petrov, A. P.
On the relative frequency stability of molecular oscillators (In English).
Radio Engineering and Electronics, 3(2): 431–433; 1958. Also in *Radiotekhnika i Elektronika*, 3(2): 298–299; February, 1958 (In Russian).
Shows the block diagram for comparing the frequencies of two molecular oscillators. The relative stability of frequency was found to be of the order of 10^{-11} over a period of about 16 minutes. The variation of frequency per second was of the order of 10^{-13} to 10^{-14}.

[189] Basov, N. G. and Prokhorov, A. M.
Possible methods of obtaining active molecules for the molecular generator (In English).
Soviet Physics JETP, 28: 184–185; July, 1955. Also in *Zhurnal Eksperimentalnoi i Teoreticheskoi Fiziki*, 28(2): 249–250; February, 1955 (In Russian).
To obtain resonance transitions between the energy levels in the molecules so as to increase the fraction of active mole-

cules in the beam, the use of an auxiliary high-frequency field is suggested.

[190] Basov, N. G. and Prokhorov, A. M.
The theory of a molecular oscillator and a power amplifier.
Discussions of the Faraday Society, (19): 96–99; 1955.
Gives expressions for the frequency of an oscillator in terms of the transitions among energy levels. Conditions for amplification are given, as well as expressions for the power-amplification ratio.

[191] Benoit, H., Grivet, P., and Guibe, L.
A maser with purely nuclear magnetic resonance (In French).
Comptes Rendus de l'Academie des Sciences (Paris), 246(26): 3608–3610; June 30, 1958.
Uses a current of water with protons oriented, due to a resonance arrangement. The water current passes through a coil tuned to 30 mc. Beats are noticed when the proton resonance frequency is sufficiently near to 30 mc, indicating that oscillations of the maser type are present. Applications are discussed.

[192] Benoit, H., Grivet, P., and Ottavi, H.
Study of a weak-field maser-type self-oscillator (In French).
Comptes Rendus de l'Academie des Sciences (Paris), 248(2): 220–223; January 12, 1959.
Presents the characteristic of the maser discussed in [191].

[193] Benoit, H., Grivet, P., and Ottavi, H.
Weak-field nuclear-magnetic-resonance maser (In French).
Comptes Rendus de l'Academie des Sciences (Paris), 247(22): 1985–1988; December 1, 1958.
Describes an instrument for nuclear-magnetic-resonance studies based on proton spin resonance in circulating benzene. A further description is given in [192].

[194] Fain, V. M.
On the oscillation equations of a molecular generator (In English).
Soviet Physics JETP, 33: 726–728; April, 1958. Also in *Zhurnal Eksperimentalnoi i Teoreticheskoi Fiziki*, 33(10): 945–947; October, 1957 (In Russian).
Derivation of equations for both stationary and nonstationary operating conditions of a molecular generator is made using a density matrix in proper approximation.

[195] Fain, V. M.
Quantum phenomena in the radio range (In Russian).
Uspekhi Fiziki Nauk, 64(2): 273–313; February, 1958.
Discusses molecular oscillators, quantum effects involved in interactions of selections in resonators with high frequency fields, spontaneous radiation, etc.

[196] Helmer, J. C.
Maser oscillators.
Journal of Applied Physics, 28(2): 212–215; February, 1957.
Using a second maser as a reference standard, observations have been made of the experimental behavior of a maser under various operating conditions. A comparison of the results is made with the theory from a new analysis which includes the velocity distribution in the beam.

[197] Helmer, J. C.
Small signal analysis of molecular beam masers.
Journal of Applied Physics, 30(1): 118–120; January, 1959.
Following an expression for the resonance polarization of a molecule in an electric field as a function of time, the author analyzes maser operation having a divergent, univelocity beam; including expressions for the relative beam intensity required to start oscillation and for the molecular Q as a function of cavity length.

[198] Kemp, J. C.
Theory of maser oscillation.
Journal of Applied Physics, 30(9): 1451–1452; September, 1958.
Derives expressions to account for the amplitude-modulated nature of the signal from an inverted spin system undergoing maser oscillation. Large amplitude nutations of the magnetization are seen to play a major role in the phenomenon.

]199] Khokhlov, R. V.
On the locking of a molecular oscillator by a small external force (In English).
Radio Engineering and Electronics, 3(4): 161–166; 1958. Also in *Radiotekhnika i Elektronika*, 3(4): 566–569; April, 1958 (In Russian).
Develops expressions for a theoretical case in which the frequency of the external force is close to that of the oscillator. Results show that the frequency of the external force corresponding to maximum amplitude is somewhat shifted from the oscillation frequency to the side of the frequency of molecular transition.

[200] Klimontovich, I. L. and Khokhlov, R. V.
Contributions to the theory of the molecular generator (In English).
Soviet Physics JETP, 32: 937–941; December, 1957. Also in *Zhurnal Eksperimentalnoi i Teoreticheskoi Fiziki*, 32(5): 1150–1155; May, 1957 (In Russian).
Discusses the theory of resonance interactions between an electromagnetic field and a molecular beam in a molecular generator. Velocity spreads are considered, as well as effects of a varying resonator temperature.

[201] Kontorovich, V. M.
On the use of two auxiliary fields to obtain emission states in quantum-mechanical amplifiers and generators (In English).
Soviet Physics JETP, 33: 820–821; April, 1958. Also in *Zhurnal Eksperimentalnoi i Teoreticheskoi Fiziki*, 33(4): 1064–1065; October, 1957 (In Russian).
Proposes the use of two fields with frequencies such that the system may be made to generate or amplify at a frequency larger than that of the auxiliary fields. Discusses pulse length of auxiliary fields and its relation to the population of the four levels.

[202] Oraevsky, A. N.
On the theory of a molecular oscillator (In Russian).
Radiotekhnika i Elektronika, 4(4): 718–723; April, 1959.
Derives equations to describe the stationary process as a function of time. The molecular oscillator can be considered as an oscillating system with an inertial nonlinearity. Locking-in of the oscillator by an external force is seen to be covered by the expressions.

[203] Prokhorov, A. M. and Lebeder, P. N.
The effect of the quality of resonator on the frequency of molecular generator (In English).
Radio Engineering and Electronics, 2(4): 208–209; 1957. Also in *Radiotekhnika i Elektronika*, 2(4): 510; April, 1957 (In Russian).
Gives expressions for the effect of the quality factor of the cavity resonator on the frequency change observed in the molecular oscillator.

[204] Prokhorov, A. M.
Molecular amplifier and generator for submillimeter waves (In English).
Soviet Physics JETP, 34: 1140–1141; December, 1958. Also in *Zhurnal Eksperimentalnoi i Teoreticheskoi Fiziki*, 34(6): 1658–1659; June, 1958 (In Russian).
Describes an amplifier using a device in which one horn's radiation crosses a number of molecular beams and reaches a second horn. Produces a maximum power of about 1 μw.

[205] Rose-Innes, A. C.
A frequency modulated microwave spectrometer for electron resonance measurements.
Journal of Scientific Instruments, 34(7): 276–278; July, 1957.
Description of an electron resonance spectrometer in the 3-cm microwave band. With frequency modulation method it is possible to use simple equipment to record spectra, and it is suitable for measurements at low temperatures and for recording of wide lines.

[206] Wells, W. H.
Maser oscillator with one beam through two cavities.
Journal of Applied Physics, 29(4): 714–717; April, 1958.
A study of the two-cavity beam maser by geometrical representation of the Schrödinger equation. A possible amplifier application is also noted.

[207] Yariv, A., Singer, J. R., and Kemp, J.
Radiation damping effects in two level maser oscillators.
Journal of Applied Physics, 30(2): 265; February, 1959.
Derives formulas to show that a nonlinear solution best fits the case for a two-level maser in regards to explaining the spontaneous radiation of an inverted two-level spin system.

Amplifiers

[208] Arams, F. R. and Krayer, G.
Design considerations for circulator maser systems.
PROCEEDINGS OF THE IRE, 46(5, pt. 1): 912–913; May, 1958.
Maximum-gain bandwidth can be obtained by using a circulator in conjunction with a maser, and receiver noise can be isolated. Reports on the various characteristics and the noise and stability requirements of the system.

[209] Basov, N. G. and Prokhorov, A. M.
Theory of the molecular generator and molecular power amplifier (In English).
Soviet Physics JETP, 30: 426–429; October, 1956. Also in *Zhurnal Eksperimentalnoi i Teoreticheskoi Fiziki*, 30(3): 560–563; March, 1956. (In Russian).
The theory of a device similar to one described in [236] is presented. Also included are the conditions of self-excitation and the expressions for frequency, amplitude, and maximum power output for the oscillator, as well as the power amplification factor and the condition for linear amplification of the amplifier.

[210] Brodzinsky, A. and Macphersen, A. C.
Maser sensitivity curves reference sheet.
Electronics, 32(8): 70; February 20, 1959.
Consists of a graph showing the relation between normalized source temperature to over-all-system sensitivity, which is useful in designing super low-noise amplifiers whose noise figures are close to unity.

[211] Chester, P. F. and Bolef, D. I.
Superregenerative masers.
PROCEEDINGS OF THE IRE, 45(9): 1287–1289; September, 1957.
A comparison is made of the characteristics of a 2-level solid-state maser amplifier operating both intermittently and superregeneratively. A superregenerator maser is found to have the advantage of stability, range of linearity, and stringency of inversion and preparation conditions, especially at high gains.

[212] Gordon, J. P. and White, L. D.
Noise in maser amplifiers—theory and experiments.
PROCEEDINGS OF THE IRE, 46(9): 1588–1594; September, 1958.
Presents the theory of noise as applied to either reflection or transmission type masers, using the concept of "effective input noise temperature." Experimental studies using an ammonia maser agreed well with the theory. An upper limit of 20°K can be placed on the absolute value of the beam temperature.

[213] Helmer, J. C. and Muller, M. W.
Calculation and measurement of the noise figure of a maser amplifier.
IRE TRANSACTIONS ON MICROWAVE THEORY AND TECHNIQUES, MTT-6(2): 210–214; April, 1958.
Review of noise performance of regenerative amplifiers. Equations were set up to interpret measurement of noise from an ammonia molecular beam maser amplifier. The measurements were made by using a double heterodyne system with a detuned maser oscillator serving as a second local oscillator.

[214] Motz, H.
Negative-temperature reservoir amplifiers.
Journal of Electronics, 2(6): 571–578; May, 1957.
Principles of maser operation are discussed theoretically with application to conditions for oscillation in a cavity and for amplification in a transmission line.

[215] Muller, M. W.
Noise in a molecular amplifier.
Physical Review, 106(1): 8–12; April, 1 1957.
A discussion of the extension of the quantum theory of noise to systemsnot in thermal equilibrium with application to masers. It predicts a correction to the noise figure usually associated with the spontaneous emission from molecules of the active medium.

[216] Pound, R. V.
Spontaneous emission and the noise figure of a maser amplifier.
Annals of Physics, 1(1): 24–32; January, 1957.
Points out some factors affecting noise figures in various maser devices and presents the application and use of a wire-circuit model for consideration.

[217] Shimoda, K., Takahasi, H., and Townes, C. H.
Fluctuations in amplification of quanta with application to maser amplifiers.
Journal of the Physical Society of Japan, 12: 686–700; June, 1957 (In English).
Develops expressions for the probability distribution of quanta for the average values, also for fractional fluctuations and applied to maser-type amplifiers.

[218] Siegman, A. E.
Gain bandwidth and noise in maser amplifiers.
PROCEEDINGS OF THE IRE, 45(12): 1737–1738; December 1957.
A comparison of two types of masers (circulator and two-port) with respect to gain-bandwidth product and noise figure.

[219] Smith, W. V.
Microwave amplification by maser techniques.
IBM Journal, 1(3): 232–238; July, 1957.
An elementary analysis has been made of the maser operation with its potentiality for broad-band, short-transit-time amplification.

[220] Stitch, M. L
Maser amplifier characteristics for one and two iris cavities.
1957 IRE WESCON CONVENTION RECORD, (pt. 3): 175–181.
Discusses noise figure, gain modulation and bandwidth characteristics of both one- and two-iris cavities in a maser amplifier. Noise temperature is also included.

[221] Stitch, M. L.
Maser amplifier characteristics for transmission and reflection cavities.
Journal of Applied Physics, 29(5): 782–789; May, 1958.
An analysis and a comparison are made of noise-temperature, bandwidth, and gain-modulation characteristics for a transmission and a reflection maser. It is concluded that the reflection maser is generally superior but is also limited by a lack of good circulators.

[222] Strandberg, M. W. P.
Quantum-mechanical amplifiers.
PROCEEDINGS OF THE IRE, 45(1): 92–93; January, 1957.
A discussion of possible alternatives to the molecular-beam amplifier such as systems involving interaction between protons or electron spins and magnetic fields. Also, it should be possible to obtain noise-free amplifiers at any frequencies.

[223] Weber, J.
Maser noise considerations.
Physical Review, 108(3): 537–541; November 1, 1957.
The calculations are given for a noise figure in a three-level maser and are shown to be little affected by the saturation field. Some aspects of spontaneous emission noise are discussed.

Gaseous Types

[224] Alsop, L. E., Giordmaine, J. A., Townes, C. H., and Wang, T. C.
Measurement of noise in a maser amplifier.
Physical Review, 107(5): 1450–1451; September, 1957.
Results of an experiment using an ammonia beam through a split cavity. A comparison has been made between theory and actual results for several ratios of loaded Q and cavity Q. A footnote gives the early history of maser amplification.

[225] Atom amplifier demonstrates unilateral gain.
Electrical Manufacturing, 62(2): 11; August, 1958.
News item and photograph of the Philco Coproration's ammonia beam maser. No details of operation are given.

[226] Atomic amplifier; gas maser.
Journal of the Franklin Institute, 266(2): 153; August, 1958.
Brief report on the Philco Company maser, which uses an ammonia beam and two electrically isolated cavities.

[227] Bonanomi, J., *et al.*
Ameliorations d'un maser a NH_3.
Helvetica Physica Acta, 30(6): 492–494; 1957.
Abstract unavailable.

[228] Bonanomi, J., *et al.*
Maser à NH_3; expériences résultats, applications (In French).
Archives des Sciences, 10: 187–193; 1957.
Abstract unavailable.

[229] Bonanomi, J., De Prins, J., Herrmann, J., and Kartaschoff, P.
High resolution microwave spectrograph (In German).

Helvetica Physica Acta, 30(4): 290–292; August 15, 1957.
Abstract unavailable.

[230] Bonanomi, J., *et al.*
Stability of NH_3 frequency standards (In French).
Helvetica Physica Acta, 30(4): 288–290; August 15, 1957.
A report of an experiment to attempt to eliminate the effects of pulling of the molecular oscillator by obtaining a frequency independent of the cavity dimensions.

[231] Bonanomi, J., Herrmann, J., De Prins, J., and Kartaschoff, P.
Twin cavity for NH_3 masers.
Review of Scientific Instruments, 28(11): 879–881; November, 1957.
A description of a system of two coupled cavities has been given. Using this system it has been found that the curve of oscillator frequency against cavity temperature is a plateau, and the "pulling" effect of the cavity has thus been reduced.

[232] "Cathode Ray," pseudonymn.
Masers—small scale atomic energy for radio.
Wireless World, 65(4): 197–200; April, 1959.
Presents the basic principles of gaseous masers and atomic clocks.

[233] Develop portable maser stable to one part in 10^9.
Machine Design, 30(9): 34–35; May 1, 1958.
Gives a brief description of an ammonia-maser oscillator capable of operating 500 hours without interruption. The ammonia is recirculated to the reservoir after 50 hours of operation, eliminating the need for auxiliary pumping equipment.

[234] Gordon, J. P. and White, L. D.
Experimental determination of the noise figure of an ammonia maser.
Physical Review, 107(6): 1728–1729; September 15, 1957.
Results of an experiment for noise measurement using two masers have been given and compared with the predicted values.

[235] Gordon, J. P., Zeiger, H. J., and Townes, C. H.
Maser—new type of microwave amplifier frequency standard and spectrometer.
Physical Review, 99(4): 1264–1274; August 15, 1955.
Experimental results of using a microwave amplifier as a high-resolution microwave spectrometer are compared with the theoretical predictions. The use with ammonia molecules is especially noted. Under certain conditions, an amplifier noise figure of unity should be possible.

[236] Gordon, J. P., Zeiger, H. J., and Townes, C. H.
Molecular microwave oscillator and new hyperfine structure in the microwave spectrum of NH_3.
Physical Review, 95(1): 282–284; July 1, 1954.
A microwave amplifier or a stable oscillator has been made which can be used as a high-solution microwave spectrometer. By directing a focused beam of NH_3 molecules into high-Q oscillating cavity, the molecules within gave up energy. By varying the frequency transmitted through the cavity through the molecular transition frequency, an emission line is seen.

[237] Helmer, J. C.
Maser noise measurement.
Physical Review, 107(3): 902–903; August 1, 1957.
3.52 ± 5 db has been found to be the average noise figure of an ammonia-beam-maser amplifier using an ammonia-beam oscillator as a primary frequency standard. Operation was at 24,000 mc.

[238] Higa, W. H.
Observations of nonlinear maser phenomena.
Review of Scientific Instruments, 28(9): 726–727; September, 1957.
Gives results of an experiment using a double-cavity ammonia maser, in which the cavities produce a beat phenomenon by oscillating individually. It shows that the maser can continue to amplify signals even in the oscillatory state.

[239] Javan, A. and Wang, T. C.
Two-cavity maser spectrometer.
Bulletin of the American Physical Society, 2(4): 209; April 25, 1957.
Discusses an ammonia-type maser developed for this purpose. Only an abstract is given.

[240] Johnson, S.
Regulated molecular beam.
Review of Scientific Instruments, 28(7): 575; July, 1957.
A brief description of an apparatus for regulating the beam flux in an ammonia maser.

[241] King, J. G. and Zacharias, J. R.
Some new applications and techniques of molecular beams.
Advances in Electronics and Electron Physics, 8: 1–88; 1956.
Ammonia masers are discussed briefly on p. 4.

[242] Maser supports relativity theory.
Electronics, 31(49): 104; December 5, 1958.
Briefly summarizes an experiment using an ammonia-type maser to determine what effect on frequency occurs when the stream of molecules travel in the same direction as the earth in its orbit as compared to traveling in the opposite direction. Einstein's special theory of relativity was confirmed by the work.

[243] Munster, A. C.
Atomic amplifier; gas maser.
Journal of the Franklin Institute, 266(2): 153; August, 1958.
The ammonia maser developed by the Philco Corporation is briefly described. No details are given.

[244] Prokhorov, A. M.
Molecular amplifier and generator for submillimeter waves (In English).
Soviet Physics JETP, 34: 1140–1141; December, 1958. Also in *Zhurnal Eksperimentalnoi i Teoreticheskoi Fiziki*, 34(6): 1658–1659; June, 1958 (In Russian).
Gives expressions for the power, and for the conditions of self-excitation, of an ammonia maser for waves shorter than 1 mm.

[245] "Quantum," pseudonym.
Molecules and microwaves; maser explained.
Electronic and Radio Engineering, 34(7): 254–257; July, 1957.
A review of the basic principles of the ammonia-type maser.

[246] Sher, N.
A two-cavity unilateral maser amplifier.
1958 IRE National Convention Record, (pt. 1): 27–35.
Following a discussion of the physical principles of an ammonia-type maser having two separated resonant cavities, the experimental results obtained are described. Results of gain and noise figure measurements are reported.

[247] Shimoda, K.
Characteristics of the beam type maser. I (In English).
Journal of the Physical Society of Japan, 12(9): 1006–1016; September, 1957.
Considers causes for velocity distribution of molecules in the maser. Relationship of amplitude to focusing voltage, as well as to frequency characteristics, are in good agreement with theory. Frequency shift caused by the unresolved hyperfine structure is discussed.

[248] Shimoda, K. and Wang, T. C.
New method for the observation of hyperfine structure of NH_3 in a "maser" oscillator.
Review of Scientific Instruments, 26(12): 1148–1149; December, 1955.
Discusses the use of a maser as a spectrometer to resolve magnetic hyperfine components in NH_3, using microwave power at frequencies of the satellite lines. An oscilloscope trace shows the structure of the weakest of the satellites.

[249] Shimoda, K.
Precise frequency of the 3,3 inversion line of ammonia (In English).
Journal of the Physical Society of Japan, 12(5): 558; May, 1957.
Uses a molecular beam maser oscillator to check the frequency measured on an absorption type Stark-Zeeman ammonia clock. The difference between the two frequencies is interpreted in terms of different populations of the quadrupole levels $F_1 = 2, 3, 4$.

[250] Shimoda, K.
Radio frequency spectroscopy using three level maser action (In English).
Journal of the Physical Society of Japan, 14(7): 954–959; July, 1959.
Following a discussion of the theory involved, a description is given of a three-level radio-frequency spectrometer which was built to observe direct l-type doubling transistors of ICN and OCS. Pumping radiation was supplied by a

klystron, and the transition was observed by a modified Pound-Knight circuit.

[251] Shimoda, K.
Three-level maser detector for ultramicrowaves (In English).
Journal of the Physical Society of Japan, 14(7): 966; July, 1959.
Develops expressions for the absorption of ultramicrowave power by gases. Recommends use of a cavity with a cell volume of ten cubic centimeters, which would allow the detection of 3×10^{-10} watts as compared to the detection of 10^{-6} watts by crystal detectors.

[252] Singer, J. R.
Proposal for a tunable millimeter wave molecular oscillator and amplifier.
IRE Transactions on Microwave Theory and Techniques, MTT-7(2): 268–276; April, 1959.
Describes a gas-type maser which uses a Stern-Gerlach molecular beam arrangement. The beam has a net magnetic moment. The frequency of operation is determined by the static magnetic field, with an upper limit of about 3 mm.

[253] Townes, C. H.
Comments on frequency-pulling of maser oscillators.
Journal of Applied Physics, 28(8): 920–921; August, 1957.
Discusses the theory of molecular-velocity distribution as related to the pulling of the oscillator frequency from the molecular resonance frequency. Gives reasons for a lack of observation of increased pulling.

[254] Troitskii, V. S.
Theory of the maser and maser fluctuations (In English).
Soviet Physics JETP, 34: 271–273; August, 1958. Also in *Zhurnal Eksperimentalnoi i Teoreticheskoi Fiziki*, 34(2): 390–393; February, 1958 (In Russian).
Presents the maser as an oscillating system with one degree of freedom, using the Basov-Prokhorov equations for steady-state oscillations. There is found to be a "soft" mode and an analog of the "hard" mode following a region of noise generation. It is determined that in an ammonia maser at room temperature the spectral-line width due to thermal noise is 10^{-4} cps.

[255] Vonbun, F. O.
Proposed method for tuning a maser cavity.
Review of Scientific Instruments, 29(9): 792–793; September, 1958.
Brief description of a method for tuning a cavity by modulating the frequency of the maser output, beating it against the auxiliary oscillator, and multiplying the beat note.

Solid-State Types

[256] Amplifier extends range of radio telescope.
Electrical Engineering, 77(2): 191–192; February, 1958.
An amplifier (three-level solid-state maser), developed by Harvard University scientists, was successfully operated at 21 cm. The article gives a description of the apparatus and explains its application in radio astronomy, including some brief history.

[257] Arams, F. R.
Low field *X*-band ruby maser.
Proceedings of the IRE, 47(8): 1373–1375; August, 1959.
Briefly describes operation of a unit at low magnetic fields (350 gauss) with a signal frequency of 9540 mc and pump frequency of 10,850 mc. Pump power was about 50 milliwatts.

[258] Arams, F. R. and Okwit, S.
Tunable *L*-band ruby maser.
Proceedings of the IRE, 47(5, pt. 1): 992–993; May, 1959.
Briefly describes the performance of a maser amplifier which operates over a frequency range of at least 850 to 2000 mc, although a tuning range of at least two octaves is believed to be possible.

[259] Artman, J. O., Bloembergen, N., and Shapiro, S.
Operation of a three-level solid-state maser at 21 cm.
Physical Review, 109(4): 1392–1393; February 15, 1958.
Gives results of the operating of a three-level solid-state maser amplifier and oscillator at 1373 mc at below 2°K.

[260] Artman, J. O.
The solid state maser.
Proceedings of the Symposium on Role of Solid State Phenomena in Electric Circuits, Polytechnic Institute of Brooklyn, Brooklyn, N. Y., 7: 71–89; 1957.
Reviews the principles of solid-state masers, followed by a review of design problems for reflection cavity masers. Describes the operation of a model under development which is for use in the region around 1400 mc.

[261] Autler, S. H.
Proposal for a maser-amplifier system without nonreciprocal elements.
Proceedings of the IRE, 46(11): 1880–1881; November, 1958.
Cavity-type solid-state masers without circulators are considered. The system is to use two matched masers and a magic T. Theoretically, the gain, noise and bandwidth would be the same as for a single maser with an ideal circulator. Actual conditions are compared with the ideal.

[262] Autler, S. H., Kingston, R. H., McWhorter, A. L., and Meyer, J. W.
Solid state maser systems.
1958 IRE WESCON Convention Record, (pt. 3): 28.
Gives abstract only, of report on systems operating at 300, 1400, 2800, and 9000 mc. Discusses isolation problems and noise sources.

[263] Autler, S. H. and McAvoy, N.
21-centimeter solid-state maser.
Physical Review, 110(1): 280–271; April 1, 1958.
Results of operating a three-level solid-state maser as an amplifier at 1382 mc with saturating power supplied at 9070 mc at a power level of 28 milliwatts.

[264] Basov, N. G., *et al.*
Molecular generator without using a molecular beam (In Russian).
Uspekhi Fiziki Nauk, 59(2): 375; 1956.
Abstract unavailable.

[265] Bergmann, S.
Three-level solid state maser.
Journal of Applied Physics, 30(1): 35–36; January, 1959.
Calculates the maximum values of the real and imaginary components of the paramagnetic susceptibility of a three-level solid-state maser. Gives expressions for the gain and bandwidth of a traveling-wave maser and compares its Q factor with that of a cavity maser.

[266] Bleaney, B.
A new class of materials for Bloembergen-type masers.
Proceedings of the Physical Society, 73(6): 937–939; June 1, 1959.
Theorizes on the compounds suitable for this use; mentions, as most promising, the following compounds: CaF_2, CdF_2, SrF_2, BaF_2, $SrCl_2$, ThO_2, and MgO.

[267] Bloembergen, N.
Electron spin and phonon equilibrium in masers.
Physical Review, 109(6): 2209–2210; March 15, 1958.
Points out that successful operation of $KCo(Cr)(CN)_6$ salt in a three-level steady-state maser is incompatible with assumption that relaxation rates are not determined by interaction between spins and the lattice vibrations regardless of operating frequencies of the maser.

[268] Bloembergen, N.
Proposal for a new type solid state maser.
Physical Review, 104(2): 324–327; October 15, 1956.
Negative absorption or stimulated emission at microwave frequencies can be obtained by using the Overhauser effect in the spin multiplet of certain paramagnetic ions. A low-noise microwave amplifier or frequency converter may be achieved through the use of nickel fluosilicate or a low-gadolinium ethyl sulfate at liquid-helium temperature. Some discussion of the operation of a solid-state maser of this type is given.

[269] Bolef, D. I. and Chester, P. F.
Some techniques of microwave generation and amplification using electron spin states in solids.
IRE Transactions on Microwave Theory and Techniques, MTT-6(1): 47–52; January, 1958.
Describes possible operation of a two-level solid-state maser with the population-inversion techniques used in nuclear magnetic resonance. Discusses continual operation of the maser and its uses as a microwave generator.

[270] Braunstein, R.

Proposal for a nuclear quadrupole maser.
Physical Review, 107(4): 1195–1196; August 15, 1957.
Suggests the use of substances having pure quadrupole spectra (such as the rare earths with atomic numbers above 50) for four-level masers. Discusses tunability, transition probabilities, elimination of external magnetic fields, etc. I_2 and its compounds may be suitable.

[271] Butcher, P. N.
Theory of three-level paramagnetic masers.
Proceedings of the Institution of Electrical Engineers, 105B (supplement 11): 684–711, 715; May, 1958.
Consists of four sections devoted to quantum theory, amplification and oscillation, output noise power spectrum and noise figures. The section on amplification and oscillation contains numerical results, whereas the other sections are primarily theoretical.

[272] Chang, W. S. C., Cromack, J., and Siegman, A. E.
Cavity and traveling-wave masers using ruby at *S*-band.
1959 IRE WESCON Convention Record, (pt. 1): 142–150.
Describes the operation of several three-level masers using ruby at 3000 mc, using either a high-efficiency cavity or a meander-line slow-traveling-wave circuit with low group velocity over the signal pass band. The traveling-wave type had broader bandwidth, greater stability and built-in nonreciprocity. The cavity gain-bandwidth products are two orders of magnitude larger than were achieved in early maser work.

[273] Chester, P. F., Wagner, P. E., and Castle J. G., Jr.
Two-level solid-state maser.
Physical Review, 110(1): 281–282; April 1, 1958.
Report of results using a two-level electron-spin system having paramagnetic defects introduced by neutron irradiation in quartz and magnesium oxide.

[274] Clogston, A. M.
Susceptibility of the three-level maser.
Journal of the Physics and Chemistry of Solids, 4(4): 271–277; 1958 (Bell Monograph 2977).
Calculations of the susceptibility by using quantum-mechanical equations of motion, including the effect of off-diagonal components of density matrix, are presented. Effect of the cavity reaction is considered, and it appears that at high levels of pumping field the result is a saturation of susceptibility.

[275] Combrisson, J., Honig, A., and Townes, C. H.
Use of electron spin resonance to realize a very high frequency oscillator or amplifier (In French).
Comptes Rendus de l'Academie des Sciences (Paris), 242(20): 2451–2453; May 14, 1956.
Induced emission in an electron resonance spectrum is used to produce a microwave oscillator or amplifier. Experimenting with silicon, it was found that the ratio of power furnished by electron emission to that required to excite the cavity was $\frac{1}{3}$. In order to obtain free oscillations, experimental details would have to be improved.

[276] Cross, L. G.
Silvered ruby maser cavity.
Journal of Applied Physics, 30(9): 1459; September, 1959.
Describes the techniques of silvering rectangular pieces of ruby which have been cut and ground to the desired cavity dimensions. Advantages are lower preparation costs, greater stability of operation, a less lossy cavity, and freedom of interchange.

[277] Crystals for masers.
Wireless World, 64(7): 330; July, 1958.
Brief report on development, at the Royal Radar Establishment (Great Britain), of crystals for a solid-state maser. Gadolinium ethyl sulphate and potassium chromicyanide in a high degree of solution as a solid solution in alum are the chief substances used. Preparation techniques are summarized.

[278] Davis, C. F., Strandberg, M. W. P., and Kyhl, R. L.
Solid-state masers and spin-lattice relaxation times.
Bulletin of the American Physical Society, 3(1): 9; January 29, 1958.
Abstract of a paper given at the annual American Physical Society Meeting, January 29–February 1, 1958. An analysis of operational properties of solid-state masers shows spin-lattice relaxation to have an important part in these devices.

[279] De Grasse, R. W.
Slow-wave structures for unilateral solid-state maser amplifiers.
1958 IRE WESCON Convention Record, (pt. 3): 29–35.
Possible slow-wave propagating structures for traveling-wave masers are discussed, followed by results of using a "comb" type structure. Pink ruby was used for the active maser material and dark ruby for the lossy material. The bandwidth was 25 mc, which could be tuned over a 350-mc range, centered at 5.9 kmc.

[280] De Grasse, R. W., Schulz-DuBois, E. O., and Scovil, H. E. D.
The three level solid state traveling wave maser.
Bell System Technical Journal, 38(2): 305–334; March, 1959.
Develops the theory for this type of maser, then compares its performance with that of cavity-type masers. A traveling-wave maser having a ruby-loaded comb structure was tested, giving a gain of 23 db at 6 kmc with a bandwidth of 25 mc. Performance characteristics of another maser, using gadolinium ethyl sulfate, are given.

[281] Ditchfield, C. R. and Forrestor, P. A.
Maser action in the region of 60°K.
Physical Review Letters, 1(12): 448–449; December 15, 1958.
Operational characteristics of a three-level solid-state maser in the range 9280 to 9520 mc. Freedom from use of liquid helium is seen to be likely.

[282] Fain, V. M.
Spontaneous radiation of a paramagnetic in a magnetic field (In English).
Soviet Physics JETP, 34: 714–715; 1958. Also in *Zhurnal Eksperimentalnoi i Teoreticheskoi Fiziki*, 34(4): 1032–1033; April, 1958 (In Russian).
Develops expressions for average power and intensity of radiation from a paramagnetic material at nearly 0° K.

[283] Foner, S., Momo, L. R., and Mayer, A.
Multilevel pulsed-field maser for generation of high frequencies.
Physical Review Letters, 3(1): 36–38; July 1, 1959.
Reports of the operation of a ruby maser, which successfully generates or amplifies at both 12.61 kmc and 19.15 kmc on a pulsed basis, 4.2° K. A peak field of 9.4 kilo-oersteds was obtained of 1000 volts with a half-period of about three milliseconds.

[284] Forward, R. L., Goodwin, F. E., and Kiefer, J. E.
Application of a solid state ruby maser to an *X*-band radar system.
1959 IRE WESCON Convention Record, (pt. 1): 119–125.
Special attention is given to a description of a low-loss ferrite TR switch that was developed to reduce leak-through from the transmitted pulse. The combined noise temperature was 65°K for the maser, circulator, mixer and IF amplifier combined, while the figure for the over-all receiver was 173°K. Improvement in the detecting range is considered, as well as antenna noise temperature.

[285] From, W.
The maser.
Microwave Journal, 1(3): 18–25; November–December, 1958.
Traces development of solid-state masers and explains their operation in some detail. Methods of designing such devices are discussed, as well as possible applications.

[286] Giordmaine, J. A., Alsop, L. E., Mayer, C. H., and Townes, C. H.
A maser amplifier for radio astronomy at *X*-band.
Proceedings of the IRE, 47(6): 1062–1069; June, 1959.
This radiometer, using a ruby maser, operates with a bandwidth of 5.5 mc at an input noise temperature, including background radiation into the antenna, of approximately 85°K. Sensitivity factors are discussed.

[287] Giordmaine, J. A., Alsop, L. E., Nash, F. R., and Townes, C. H.
Paramagnetic relaxation at very low temperatures.
Physical Review, 109(2): 302–311; January 15, 1958.
A series of experiments using paramagnetic resonance at microwave frequencies and in the 1°–4°K temperature range. Implications of the relaxation process for masers are presented on pp. 310–311.

[288] Gold, T.
Range of radio telescopes extended by new amplifier: maser.
Journal of the Franklin Institute, 265(1): 83–84; January, 1958.

Briefly reviews operating features of a solid-state maser developed by Harvard University to be used in their radio telescope. The maser uses a single crystal of potassium cobalticyanide, kept at a temperature of 2°K, and it operates in the 21-cm band.

[289] Heffner, H.
Maximum efficiency of the solid-state maser.
PROCEEDINGS OF THE IRE, 45(9): 1289; September, 1957.
Gives an estimation of the efficiency of a three-state maser for operation at saturation.

[290] Herold, E. W.
Future circuit aspects of solid-state phenomena.
Proceedings of the Symposium on the Role of Solid-State Phenomena in Electric Circuits, Polytechnic Institute of Brooklyn, Brooklyn, N. Y., 7: 3–31; 1957. Also in PROCEEDINGS OF THE IRE, 45(11): 1463–1474; November, 1957.
A discussion of superconductivity, molecular amplification, magnetic effects in semiconductors and nonlinear capacitance in junctions. Specific information on solid-state masers is also given.

[291] Howarth, D. J.
The physics of the solid-state maser.
IRE TRANSACTIONS ON COMPONENT PARTS, CP-6(2): 81–93; June, 1959. (Reprinted from *Royal Radar Establishment Journal*, April, 1958).
Discusses the theory of the three-level solid-state maser, using a quantum mechanical description.

[292] Itoh, J.
Proposal for a solid state radio-frequency maser (In English).
Journal of the Physical Society of Japan, 12(9): 1053; September, 1957.
The four levels into which a nuclei with spin 3/2 will split in a magnetic field when strong axially symmetrical nuclear quadrupole interaction exists in a single crystal are analyzed for suitability for maser operations at radio frequencies.

[293] Javan, A.
Description of a Raman type two-level maser.
Bulletin of the American Physical Society, 3(3): 213; May1 1958.
Abstract of a paper presented at the spring meeting of the American Physical Society, May 1–3, 1958. Treats the case in which two photons are present, having a frequency difference close to the energy separation of the two levels. Amplification at the lower frequency takes place. Noise figures, magnetic susceptibility, and applications to ferrites are also discussed.

[294] Javan, A.
Theory of a three-level maser.
Physical Review, 107(6): 1579–1589; September 15, 1957.
Develops a theory which covers the discrepancies between a semiclassical treatment based on population differences of various levels and actual effects deduced from a detailed analysis of the subject. Theory covers a gaseous system as well as two cases of paramagnetic materials. Four-level masers are also discussed.

[295] Kikuchi, C., Lambe, J., Makhov, G., and Terhune, R. W.
Ruby as a maser material.
Journal of Applied Physics, 30(7): 1061–1067; July, 1959.
Outlines the reasons for the original choice of ruby. Gives some measurements of the parameters in the spin Hamiltarian and of spin relaxation times. Discusses the relative advantages of single- and double-pump modes of operation of a four-level maser and gives measurements of the oscillator power.

[296] Kingston, R. H. K.
A UHF solid-state maser.
PROCEEDINGS OF THE IRE, 46(5, pt. 1): 916; May, 1958.
A new type of maser has been built using a pump-frequency circuit as a resonant cavity and a signal-frequency circuit of the lumped-constant type. This gives independent turning ranges and makes full use of the whole volume of the crystal.

[297] Kingston, R. H. K.
A UHF solid-state maser.
IRE TRANSACTIONS ON MICROWAVE THEORY AND TECHNIQUES, MTT-7(1): 92–94; January, 1959.
Describes a maser operating in the frequency range of 300 to 500 mc. It uses chromium-doped cobalticyanide, a cavity mode at the pumping frequency, and a tuned loop at the operating frequency, thus avoiding previous design complications.

[298] Lax, B. and Gatos, H. C.
The remarkable "Maser" story.
Technology Review, 61(7): 360, 374; May, 1959.
Describes briefly the UHF solid-state maser developed by M.I.T. for use in their radar apparatus which contacted the planet Venus. General advantages and future possibilities are mentioned.

[299] Llewellyn, P. M.
A solid-state paramagnetic-resonance spectrometer.
Journal of Scientific Instruments, 34(6): 236–239; June, 1957.
A description of a sensitive instrument for use in the frequency range 9000–10,000 mc at various temperatures down to 14°K.

[300] McWhorter, A. L., Meyer, J. W., and Strum, P. D.
Noise figure measurement on a solid state maser.
Proceedings of the National Electronics Conference, 13: 377–384; 1957.
The noise temperature is found not to exceed 2+°K in a three-level solid-state maser using $K_3Cr(CN)_6$ as a paramagnetic salt and amplifying at 2800 mc. Description of materials, apparatus, and amplifier characteristics are given. Figures refer to maser only, not to the entire system.

[301] McWhorter, A. L., Meyer, J. W., and Strum, P. D.
Noise temperature measurement on a solid state maser.
Physical Review, 108(6): 1642–1644; December 15, 1957.
Noise temperature for a three-level maser with an upper limit of 20°K was measured by comparison with an argon discharge noise tube using a Dicke radiometer method. Results are reported.

[302] McWhorter, A. L. and Meyer, J. W.
A solid state maser amplifier.
Physical Review, 109(2): 312–318; January, 1958.
Description of operation at 2800 mc using a dual-frequency cavity at 1.25°K. Theory and experimental observations of the maser have been compared as both an amplifier and an oscillator.

[303] McWhorter, A. L. and Arams, F. R.
System-noise measurement of a solid-state maser.
PROCEEDINGS OF THE IRE, 46(5, pt. 1): 913–914; May, 1958.
An amplifier system has been built with a low-loss *S*-band circulator and a solid-state maser. The paper discusses the method used to measure noise and the sources of noise in the system.

[304] Makhov, G., Kikuchi, C., Lambe, J., and Terhune, R. W.
Maser action in ruby.
Physical Review, 109(4): 1399–1400; February 15, 1958.
A brief report of investigations of electron-spin resonance properties of ruby, in a three-level maser operating at 2°K. A net gain of 20 db was observed.

[305] Malvern maser.
Engineering, 185(4812): 699; May 30, 1958.
A brief description of the Royal Radar Establishment's maser, which uses a paramagnetic salt. Methods used for the growth of crystals are also discussed.

[306] Maser amplifier brings Venus ten times closer.
Radio Electronics, 29(6): 68; June, 1958.
A brief announcement about the synthetic ruby maser developed by Columbia University for the Naval Research Laboratory radio telescope.

[307] Maser development offers wider uses.
Aviation Week, 66(18): 37; May 6, 1957.
A news item with description of garnet maser under development by Bell Telephone Laboratories and Harvard University, as created by H. Suhl and C. L. Hogan.

[308] Maser operates at 2 degrees K for radio telescope.
Electronics, 31(4): 30; January 24, 1958.
Brief report of further development of a maser at Harvard University for use in a radio telescope—a three-level solid-state maser operating at 21 cm.

[309] Masers probe outer space.
Electronics, 31(1): 12, 14; January 3, 1958.
Report of successful operation of a three-level solid-state maser at Harvard University at 21-cm waveband length

Points out possible applications and gives a general description of its operation.

[310] Meyer, J. W.
The solid-state maser—a supercooled amplifier.
Electronics, 31(17): 66–71; April 25, 1958.
A basic article presenting history, description, characteristics, etc., of the two-level molecular maser (gaseous) and the three-level solid-state maser, with a few words about future possibilities.

[311] Microwave unit may improve radar.
Aviation Week, 66(7): 67; February 18, 1957.
Brief account of a new type of solid-state microwave device (maser) with extremely low noise level that has been developed at Bell Telephone Laboratories.

[312] Morris, R. J., Kyhl, R. L., and Strandberg, M. W. P.
A tunable maser amplifier with large bandwidth.
PROCEEDINGS OF THE IRE, 47(1): 80–81; January, 1959.
Describes an X-band maser which uses a ruby crystal. It has a 20-mc bandwidth at 10 db gain, and can be tuned from 8400 to 9700 mc.

[313] New atomic amplifiers developed.
Westinghouse Engineer, 18(5): 146–147; September, 1958.
Brief description and illustration of the Westinghouse Research Laboratories' two-level solid-state maser, which uses a quartz crystal operating at 4.2°K.

[314] New solid-state oscillator for microwaves.
Bell Laboratories Record, 35(3): 109; March, 1957.
Announcement of successful operation of a new solid-state device which was developed by D. Scovil, G. Feher, and H. Seidel (of the Laboratories). It can be operated as an oscillator as well as an amplifier and is based on the maser principle.

[315] Range of radio telescope extended by new amplifier.
Journal of the Franklin Institute, 265(1): 83–84; January, 1958.
New (3-level) maser amplifier developed by Harvard University has been successfully operated. Potentialities include certain radar systems as well as radio astronomy.

[316] Research yields new solid-state oscillator for microwaves.
Industrial Science and Engineering, 4(3): 62, 64, 65; 1957.
Abstract unavailable.

[317] Rodrigue, G. P.
Microwave properties and applications of garnet materials.
1957 IRE WESCON CONVENTION RECORD, (pt. 3): 182–200.
A summary of known microwave properties of new garnet materials and a comparison with more conventional ferrites is presented. To help explain operation of some of the new devices, recent theories are outlined and possible applications are given.

[318] Ruby maser.
Journal of the Franklin Institute, 226(5): 423–424; November, 1958.
The University of Michigan's ruby maser is briefly described.

[319] Ruby maser for new telescope.
Electronics, 31(36): 23; September 5, 1958.
Brief report of advantages afforded the University of Michigan radio telescope by a ruby maser.

[320] Schulz-DuBois, E. O., Scovil, H. E. D., and DeGrasse, R. W.
Use of active material in three-level solid state masers.
Bell System Technical Journal, 38(2): 335–362; March, 1959.
Presents experimental data for two typical paramagnetic salts used as active materials, which make use of favorable ratios of signal-to-idler relaxation time. Properties of practical isolator materials are surveyed, including high-concentration paramagnetic and polycrystalline ferrimagnetic materials.

[321] Scovil, H. E. D., Feher, G., and Seidel, H.
Operation of a solid state maser.
Physical Review, 105(2): 762–763; January 15, 1957.
A detailed description of the operation at 9 kmc of a maser oscillator using gadolinium ethyl sulfate at liquid-helium temperature.

[322] Scovil, H. E. D. and Schulz-DuBois, E. O.
Three-level masers as heat engines.
Physical Review Letters, 2(6): 262–263; March 15, 1959.
Develops expressions for the maser efficiency as a heat engine and shows it to be limited by the same factors as a Carnot engine. Generation of microwaves by thermal excitation at two temperatures seems experimentally probable. Heat is seen excluded as a source of energy for parametric amplification.

[323] Scovil, H. E. D.
A three-level solid-state maser.
Bell Laboratories Record, 36(7): 242–246; July, 1958.
Presents a brief history of the maser and a description, including characteristics, of low thermal noise and energy levels and giving a mechanical analogy.

[324] Scovil, H. E. D.
The three-level solid-state maser.
IRE TRANSACTIONS ON MICROWAVE THEORY AND TECHNIQUES, MTT-6(1): 29–38; January, 1958. (Bell Monograph 3001).
An introduction to maser-amplification techniques with the emphasis on the three-level solid-state type. Presents the physical properties of paramagnetic salts, basis of the three-level excitation method, and some design considerations.

[325] Senitzky, I. R.
Behavior of a two-level solid state maser.
Physical Review Letters, 1(5): 167–168; September 1, 1958.
Explains the amplitude modulation observed in certain masers, such that the behavior can be expressed by a system of coupled equations, one for the spin and one for the field, with energy transfers taking place between the two degrees of freedom. Observations bear out the theory.

[326] A solid-state maser oscillator.
IRE STUDENT QUARTERLY, 3(4): 22–23; May, 1957.
A news items giving a brief history and a description.

[327] Solid state oscillator for microwave frequencies.
Engineer, 203(5276): 389; March 8, 1957.
Describes an experimental maser amplifier using gadolinium ethyl sulphate, which is an ionically bound paramagnetic salt, as the active agent.

[328] Strandberg, M. W. P.
Computation of noise figure for quantum-mechanical amplifiers.
Physical Review, 107(6): 1483–1484; September 15, 1957.
A noise-figure expression is derived in terms of physical quantities describing electromagnetic structure and paramagnetic salts.

[329] Strandberg, M. W. P.
Gyratron—a new solid-state quantum-mechanical amplifier.
Bulletin of the American Physical Society, 2(1): 36; January 30, 1957.
Abstract of a paper presented at the annual American Physical Society Meeting, January 30–February 2, 1957; describes possible operating characteristics of a new device called the gyratron, and its uses.

[330] Strandberg, M. W. P.
Inherent noise of quantum-mechanical amplifiers.
Physical Review, 106(4): 617–620; May 15, 1957.
Gives a derivation of noise figure on limiting sensitivity for quantum-mechanical amplifiers of either traveling-wave or resonant-cavity design.

[331] Strandberg, M. W. P., Davis, C. F., Faughnan, B. W., Kyhl, R. L., and Wolga, G. J.
Operation of a solid-state quantum-mechanical amplifier.
Physical Review, 109(6): 1988–1989; March 15, 1958.
The S-band amplifier was operated at 4.2°K with a computed noise temperature of less than 4.5°K. Comparison is made with a similar device.

[332] Strandberg, M. W. P.
The Versitron—a new solid-state quantum mechanical amplifier.
Proceedings of the Symposium on the Role of Solid-State Phenomena in Electric Circuits, Polytechnic Institute of Brooklyn, Brooklyn, N. Y., 7: 63–70; 1957.
Discusses basic principles and features of a solid-state maser amplifier. Emphasizes noise figures and noise-temperature properties of the device.

[333] Tenney, H. D., Roberts, R. W., and Vartanian, P. H.
An S-band traveling wave maser.
1959 IRE WESCON CONVENTION RECORD, (pt. 1): 151–155.
Discusses several slow wave structures of wide-band travel-

ing wave masers, operating at 3 kmc. Both garnet and pink ruby were used. Gains in excess of 15 db over a bandwidth of 60 mc were achieved. The garnet slab provided nonreciprocal reverse loss and also smoothed out the gain fluctuation of the maser due to regeneration and degeneration.

[334] Theissing, H. H., Dieter, F. A., and Caplan, P. J.
Analysis of the emissive phase of a pulsed maser.
Journal of Applied Physics, 29(12): 1673–1678; December, 1958. Also in 1958 IRE NATIONAL CONVENTION RECORD, (pt. 1): 19–26.
A pulsed solid-state maser's operation in the emissive phase is discussed, and it is shown that equations for this phase are amenable to machine computation. Gives numerical results for various values of such variables as relaxation times, input fields and oscillation characteristics. An interpretation is given with regard to both regeneration and superregeneration modes of operation.

[335] Weber, J.
Masers.
Reviews of Modern Physics, 31(3): 681–710; July, 1959.
Reviews the principles of the solid-state maser, then discusses specific types of masers, including ruby masers. Noise performance is described, followed by a brief discussion of masers at low frequencies and in infrared. There are nine pages of matrix elements and energy levels for ruby.

[336] Weintraub, S.
A new microwave amplifier.
Nature, 179(4566): 903; May, 1957. Also in *Wireless World*, 63(5): 212; May 4, 1957.
Gives a brief review and description of the first successful operation of a solid-state maser.

[337] Wessel, G. K.
A UHF ruby maser.
PROCEEDINGS OF THE IRE, 47(4): 590; April, 1959.
A tunable maser operates over the signal frequency range of 380–450 mc. A gain of 15 db and a bandwidth of 100 kc were observed at 1.7°K. Acting as an oscillator, the power output was less than 1 μw.

[338] Zverev, G. M., Kornienko, L. S., Manenkov, A. A., and Prokhorov, A. M.
A chromium corundum paramagnetic amplifier and generator (In English).
Soviet Physics JETP, 34: 1141–1142; 1958. Also in *Zhurnal Eksperimentalnoi i Teoreticheskoi Fiziki* 34(6): 1660–1661; June, 1958 (In Russian).
Describes certain basic design criteria for a solid-state maser. At approximately 2°K, the system became self-excited and acted as a generator.

Optical, Radio-Frequency and Infrared Types

[339] Barker, W. A.
Raser: new solid amplifier reported.
Electronics, 32(18): 25; May 1, 1959.
A brief announcement of the commencement of a project to develop a solid-state quantum-mechanical amplifier operating in the radio-frequency range. It depends upon induced nuclear-spin transitions.

[340] Javan, A.
Possibility of production of negative temperature in gas discharges.
Physical Review Letters, 3(2): 87–89; July 15, 1959.
Theorizes upon the conditions most suitable for the operation of an optical maser. The differences between pure gases and gas mixtures are developed. Gases considered include neon, helium, and a mixture of krypton and mercury.

[341] Sanders, J. H.
Optical maser design.
Physical Review Letters, 3(2): 86–87, July 15, 1959.
Discusses the problems involved in an optical maser. Suggests the use of a discharge in the working medium. Recommends the use of a Fabry-Perot etalon for the detection of the maser oscillations.

[342) Schawlow, A. L. and Townes, C. H.
Infrared and optical masers.
Physical Review, 112(6): 1940–1949; December 15, 1958.
Discusses the application of maser techniques to the optical and infrared regions. Shows that a resonant cavity of centimeter dimensions, and pumping with incoherent light, would result in maser oscillations. Suggests use of both multimode and single-mode cavities. Discusses a system using potassium vapor. The ultraviolet region is considered the shortest usable wavelength.

Atomic Clocks

[343] Arditi, M. and Carver, T. R.
Atomic clock for space travelers' use.
Electrical Engineering, 77(6): 571; June, 1958.
A summary of a paper presented at the 1958 IRE Convention entitled "Gas cell 'atomic clock' using optical pumping and optical detection." For abstract, see [345].

[344] Arditi, M. and Carver, T. R.
Frequency shift of the zero-field hyperfine splitting of Cs^{133} produced by various buffer gases.
Physical Review, 112(2): 449; October 15, 1958.
Use optical pumping and optical detection in studying the effects of various noble buffer gases upon the frequency shift in Cs^{133}, using equipment previously described (see [346]), following a suggestion by Dicke for an atomic sodium clock employing buffer gas reduction of the Doppler width.

[345] Arditi, M. and Carver, T. R.
A gas cell "atomic clock" using optical pumping and optical detection.
1958 IRE NATIONAL CONVENTION RECORD, (pt. 1): 3–9.
Describes the theory and operation of cesium-cell and sodium-cell frequency standards, which use polarized resonance light in order to increase the population difference between the energy levels. A frequency stable to one part in 10^{10} is anticipated.

[346] Arditi, M. and Carver, T. R.
Optical detection of zero-field hyperfine splitting of Na^{23}.
Physical Review, 109(3): 1012–1013; February 1, 1958.
Describes optical detection system; gives value of the hyperfine splitting of Na^{23} in the ground state, which is slightly lower than the value given by atomic beam measurements. Effects of buffer gas pressure in shifting the hyperfine frequency are described.

[347] Beck, A. H. W. and Lytollis, J.
Construction of a mobile caesium frequency standard.
Proceedings of the Institution of Electrical Engineers, 105B (supplement 11): 712–715; May, 1958.
(See also [377] below).
The circuitry and illustrations of the frequency standard are coupled with a description of the components of the system, such as the cesium oven, the magnets, paddle tuners, connectors, etc. In the discussion which follows, comments are made on the relation of noise and populations of states in two-level and three-level masers.

[348] Bell, W. E., Bloom, A., and Williams, R.
A microwave frequency standard employing optically pumped sodium vapor.
IRE TRANSACTIONS ON MICROWAVE THEORY AND TECHNIQUES, MTT-7(1): 95–98; January, 1959.
Describes construction details of the system. Light from a sodium lamp is used to produce population difference between the two quantum levels. Predicts that an accuracy of one part in 10^{10} can be achieved.

[349] Bonanomi, J. and Herrmann, J.
Ammonia frequency standard.
Helvetica Physica Acta, 29: 224–226; 1956.
Describes equipment which operates at 23,870 mc with a variation of 2×10^{-9} per day. To improve the stability, a maser is introduced.

[350] Bonanomi, J. and Herrmann, J.
Determination of the inversion frequency of ammonia.
Helvetica Physica Acta, 29: 451–452; 1956.
Uses a maser-type device to arrive at a frequency of $23{,}870{,}129.42\pm0.05\pm0.12$ kc.

[351] Clock produces microwaves direct; varies one second in 300 years.
Chemical and Engineering News, 33(6): 502, 504; February 7, 1955.
A news item describing the ammonia-type clock.

[352] Dicke, R. H.
Collision reduced Doppler effect. A sodium clock?
1955 IRE Convention Record, (pt. 10): 181.
Gives only an abstract of a paper which discussed reduction of the Doppler effect by adding a helium atmosphere to the alkali metal vapor. Optical pumping and techniques for coherent pulse-induced radiations were mentioned in original paper.

[353] Essen, L.
Atomic clocks.
Journal of the Institution of Electrical Engineers, 4(48): 647–653; December, 1958.
Describes the operation and advantages of a cesium-type atomic clock. Also discusses quartz-clock calibration, variations in mean solar time, and masers. A review is made of the comparison of the British and U. S. atomic frequency standards.

[354] George, W. D.
Need for a new type frequency and time standard.
Proceedings of the IRE, 42(9): 1349; September, 1954.
Points out the problems in definitions and operational standards currently used for time and frequency. Because, at the present time, the appropriate standard is the period of a molecular, atomic, or nuclear vibration, several atomic clocks should be built and observed in an effort to obtain correlation to at least one part in 10^9.

[355] Ince, C. R. S.
Atomic clocks and frequency stabilization.
Journal of Applied Physics, 23(12): 1408–1409; December, 1952.
Some corrections are made for the paper by Townes (see [369]).

[356] Lewis, F. D.
Frequency and time standards.
Proceedings of the IRE, 43(9): 1046–1068; September, 1955.
Various frequency and time standards are described. Included also is a discussion of atomic and molecular frequency standards such as the ammonia maser.

[357] Lyons, H.
Atomic clocks.
Scientific American, 196(2): 71–82; February, 1957.
A discussion and general description of the atomic, cesium and maser clocks.

[358] Mc Coubrey, A. O.
The Atomichron—an atomic-frequency standard—physical foundation.
1958 IRE National Convention Record, (pt. 1): 10–13.
Presents the theory of an atomic-frequency standard, particularly the operation of atomic-beam resonance tubes.

[359] Mc Coubrey, A. O.
Results of the comparison: Atomichron–British cesium beam standard.
IRE Transactions on Instrumentation, I-7(3–4): 203–206; December, 1958.
Experiments to compare the British and U. S. standards are described. Final differences amounted to only about 2.2 parts in 10^{10}.

[360] Mainberger, W. and Orenberg, A.
The Atomichron—an atomic frequency standard—operation and performance.
1958 IRE National Convention Record, (pt. 1): 14–18.
The operation of a cesium-type frequency standard is explained and circuit diagrams are given. An accuracy of one part in 10^9 is provided. Test results are given.

[361] Mockler, R. C., Salazar, H., Fey, L., Barnes, J., and Beehler, R.
The ammonia maser as an atomic frequency and time standard.
IRE Transactions on Instrumentation, I-7(3–4): 201–202; December, 1958.
After various factors affecting such devices are described, there is a discussion of the operation of an experimental type having a frequency stability of 1×10^{-11} or better for short periods.

[362] Peter, M. and Strandberg, M. W. P.
Efficiency of frequency measurements with an atomic clock.
Proceedings of the IRE, 47(1): 92–93; January, 1959.
Presents the theory of frequency measurements. Concludes that a spectroscope with a sufficiently narrow natural spectral width is required for an atomic clock of optimum efficiency.

[363] Plotkin, H. H. and Reder, F. H.
Atomic clocks and microwave amplification.
Physics Today, 9(6): 44–46; June, 1956.
Summary of a symposium held February 29th and March 1st, 1956, devoted both to basic ideas and to design criteria.

[364] Reder, F. H.
Proposed feasibility study of frequency shift in sealed atomic beam frequency standard.
Proceedings of the IRE, 47(9): 1656; September, 1959.
Reports on the comparison of British and U. S. atomic beam frequency standards. Offers possible reasons for the errors observed in a sealed Cs beam frequency standard and suggests ways of determining if a deteriorating vacuum in the beam tube is involved.

[365] Scheibe, A.
Pendulum, quartz and atomic clocks as time standards (In German).
Zeitschrift für Angewandte Physik, 5(8): 307–317; August, 1953.
Discusses and compares performance of recent forms of standard clocks. Describes the basic principles of the Shortt, Riefler, and Schuler pendulum clocks, the standard quartz clocks at various places in England, France, Germany, and the United States of America, and the NH_3 and Cs atomic clocks. Performance of the quartz clocks indicates they are better than the best astronomical pendulum clocks. It is stated that the "NH_3 clock is inferior to a good quartz clock, but the proposed Cs clock should be superior in performance."

[366] Shimoda, K.
Atomic clocks and frequency standard on an ammonia line: part 1 (In English).
Journal of the Physical Society of Japan, 9(3): 378–386; May–June, 1954.
Theoretical and experimental examinations are made of the various errors in an atomic clock using the 3-3 line of ammonia. Also given is a brief description of an experimental Stark modulation atomic clock. In order that the fractional error be kept under one part in 10^8, it is necessary that there be a high degree of frequency-insensitive multiplier output and that the generator and detector be well-matched to the waveguide.

[367] Shimoda, K.
Atomic clocks and frequency standards on an ammonia-line: parts 2 and 3 (In English).
Journal of the Physical Society of Japan, 9(4): 558–575; July–August, 1954.
In order to eliminate the causes for error in atomic clocks, the use of Zeeman and Faraday effects were observed. A theoretical investigation for accurate atomic-clock design was made of the nonreciprocal transmission characteristics of a waveguide absorption cell in an axial magnetic field. The plan consists of using Stark, source, and Zeeman modulation which is free from errors due to reflections in the microwave line. Preliminary results show accuracy within 10^{-7} possible.

[368] Shimoda, K.
Characteristics of the beam-type maser; part 2 (In English).
Journal of the Physical Society of Japan, 13(8): 939–947; August, 1958.
Reports on an experimental ammonia-maser frequency standard. Effects of focusing voltages and cavity timing on frequency are compared with theoretical values. Estimates effect of the velocity spread of the molecules.

[369] Townes, C. H.
"Atomic" clocks and frequency stabilization on microwave spectral lines.
Journal of Applied Physics, 22(11): 1365–1372; November, 1951.
Discusses microwave gas absorption lines and the various types of errors in frequency stabilizaton due to the nature

of their lines and to fundamental thermal noise. Accuracy of the order of one part in 10^{12} for a short time are the limits shown for time standards synchronized with microwave absorption in ammonia or resonances in molecular or atomic beams. Smaller fractional errors over longer periods of time will be possible.

[370] United States sharpens its time standard.
Product Engineering, 28(18): 16; November 4, 1957.
A news item about two types of atomic clock (one is ammonia, the other, cesium) time standards undergoing tests at the National Bureau of Standards.

[371] Vasnieva, G. A., Grigoriants, V. V., Zhabatinski, M. E., Klyshko, D. N., Sverdlov, I. L., and Sverchkov, E. I.
Molecular frequency standard (In English).
Radio Engineering and Electronics, 3(4): 167–168; 1958. Also in *Radiotekhnika i Elektronika*, 3(4): 569–570; April, 1958 (In Russian).
Describes a circuit for determining the value of the frequency of a quartz oscillator by means of a molecular oscillator, with an error not exceeding 10^{-9} of the nominal value. A telephone receiver is used to tune in conjunction with a cathode ray tube.

[372] Zacharias, J. R., Yates, J. G., and Haun, R. D. Jr.
An atomic frequency standard.
1955 IRE CONVENTION RECORD, (pt. 10): 180.
Presents abstract of a report. The system uses a cesium beam involving resonant cavities in which either absorption or stimulated emission by the atoms of the beam takes place. An accuracy of one part in $10^{10.5}$ is expected over long periods.

Miscellaneous Items

[373] Alsop, L. E., Giordmaine, J. A., Mayer, C. R., and Townes, C. H.
Observations using a maser radiometer at 3-cm wavelength.
Astronomical Journal, 63: 301; September, 1958.
Abstract unavailable.

[374] Ewen, H. I.
A thermodynamic analysis of maser systems.
Microwave Journal, 2(3): 41–46; March, 1959.
Points out the role masers have and will have in radio astronomy. A thermodynamic approach to system analysis is introduced. There is a discussion of extraterrestrial noise sources, both celestial and man-made, and their relation to masers.

[375] Fain, V. M.
Saturation effect in a system with three energy levels (In English).
Soviet Physics JETP, 33: 991–995; May, 1958. Also in *Zhurnal Eksperimentalnoi i Teoreticheskoi Fiziki*, 33: 1290–1294; November, 1957 (In Russian).
The effect of a high-frequency alternating field with given harmonics on a system with three energy levels is analyzed mathematically. Gives expressions, applicable to maser operations, for dielectric constant or permeability.

[376] Feyman, R. P., Vernon, F. L., Jr., and Hellwarth, R. W.
Geometrical representation of the Schrödinger equation for solving maser problems.
Journal of Applied Physics, 28(1): 49–52; January, 1957.
Resonance behavior of a quantum system using only a pair of energy levels is described in a simple rigorous geometrical picture. With this system it is possible to analyze various maser-type devices.

[377] Goudet, G.
Report of advance in microwave theory and techniques in Western Europe—1958.
IRE TRANSACTIONS ON MICROWAVE THEORY AND TECHNIQUES, MTT-7(3): 327–330; July, 1959.
Includes references to three French articles on quantum-mechanical amplifiers.

[378] Siegman, A. E., and Morris, R. J.
Proposal for a "staircase" maser.
Physical Review Letters, 2(7): 302–303; April, 1959.
Proposes using the phenomenon of inversion by adiabatic fast passage of a single electron-spin resonance transition in a multilevel system. Operating points, at which two successive inversions can be performed by the same pump oscillator in a single sweep of the dc magnetic field, can be found in common maser materials.

[379] Weiss, M. T.
Quantum derivation of energy relations analogous to those for nonlinear reactances.
PROCEEDINGS OF THE IRE, 45(7): 1012–1013; July 1, 1957.
Points out that the Manley-Rowe relations are almost self-evident in a quantum-mechanical system. Energy relations are fully developed on this basis and are shown to be particularly significant in analyzing multilevel solid-state masers.

IV. AUTHOR INDEX