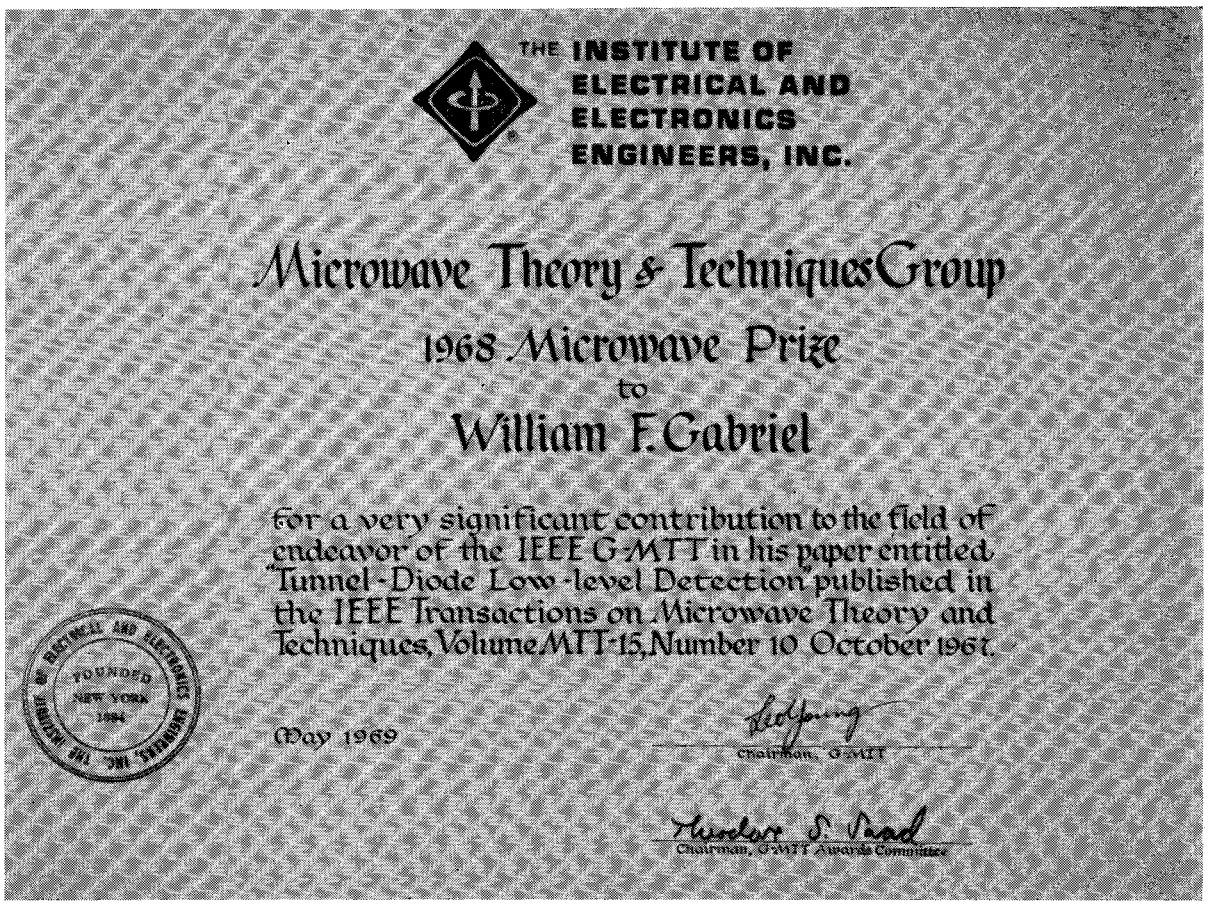


1969 International Microwave Symposium

J. B. HORTON, CHAIRMAN, TECHNICAL PROGRAM COMMITTEE

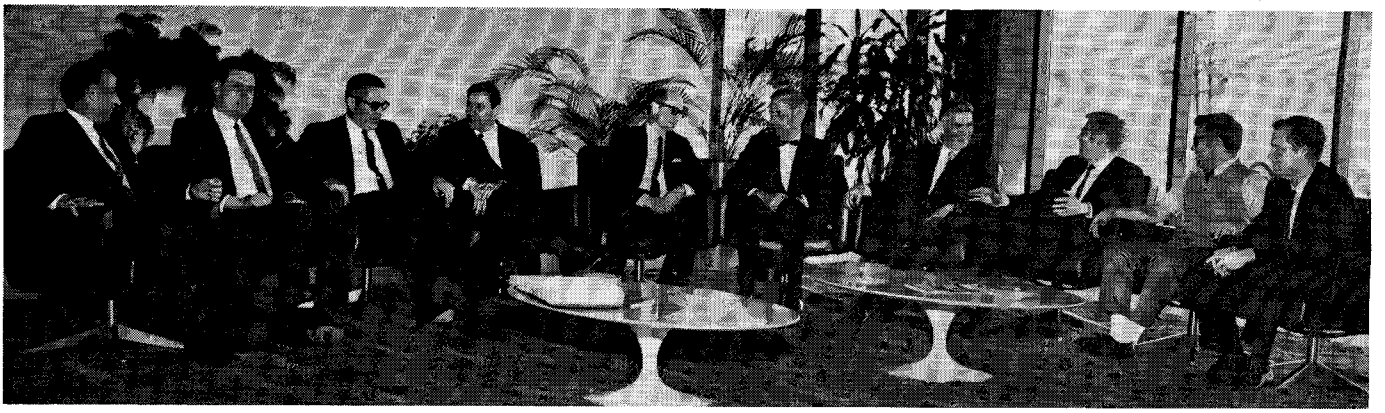
THE Dallas Chapter of the IEEE Group on Microwave Theory and Techniques hosted the 1969 IEEE G-MTT International Microwave Symposium, May 5–7, 1969, at the Marriott Motor Hotel, Dallas, Tex. This year's Symposium was highlighted by a greatly expanded and comprehensive technical program which included twelve sessions and three panel discussions. For the first time, parallel sessions were held in both the regular sessions and panel discussions, and late news items were included as a feature of the program. Ninety-six papers, including twelve late news items, were included in the program; eighteen panel members made up the three discussion panels. The expanded program resulted in a Symposium Digest of over 500 pages.

Several other outstanding features included in the three-day program were a keynote session, banquet, ladies' program, and a special offer to non-members of a year's G-MTT membership if they joined IEEE at the Symposium. All functions were held at the Marriot Motor Hotel complex with good attendance at all technical sessions and social functions. The registered attendance was 730.

The Symposium was opened with introductory remarks by J. C. Sadler, Co-Chairman of the Symposium Steering Committee. Leo Young, ADCOM Chairman, presented the keynote address entitled "IEEE, G-MTT and You." The banquet speaker was B. F. Coggin, Vice-President of North American Rockwell Corporation. His talk was entitled "Apollo and Beyond" and featured many of the interesting highlights of the space program being conducted by the U. S. The welcoming address at the first meeting of the ladies' program was presented by Mrs. Erik Jonsson, wife of the mayor of Dallas.

Evening Panel Discussions

Three parallel panel discussions were conducted on Monday evening. The subjects covered were microwave power, microwave integrated circuits, and noise in devices and systems. Each panel member gave a fifteen-minute review of



Symposium Steering Committee. *Left to right*: M. B. O'Neal, *Finance;* Julius Lange, *Publicity;* R. R. Webster, *Program;* J. C. Sadler, *Co-Chairman;* B. R. Hallford, *Co-Chairman;* H. F. Cooke, *Secretary;* S. R. Sandefer, *Local Arrangements;* F. E. Emery, *Digest;* R. E. Greenwood, *Local Arrangements;* J. B. Horton, *Program.*

his own field of interest, after which the sessions were open to general discussion with audience participation.

The session on Microwave Energy Applications, Noncommunication, was organized by M. C. Horton (Bendix Research Laboratories). Panel members were W. A. Geoffrey Voss (University of Alberta), *Chairman*; J. A. Jolly (Varian); W. C. Brown (Raytheon); L. D. Sher (University of Pennsylvania); K. E. Mortenson (RPI); and G. B. Walker (University of Alberta).

The panel covered a wide range of applications of microwave power engineering. James Jolly discussed heating and drying applications established by the electronic oven; William Brown discussed concepts of harnessing and transmitting power, including transmission of energy through microwave beams and harnessing power from sun to earth. G. B. Walker discussed the development of accelerators for high-energy physics; K. E. Mortenson gave an interesting presentation on Project Tubelight. In the final talk, L. D. Sher succeeded in clearly differentiating between biological effects and biological hazards associated with microwave energy. Attendance at the session was approximately 70. In retrospect, the five speakers appear to have summarized the topics covered at the IMPI Symposium held three weeks later in Canada.

The session on Techniques for Fabrication and Production of Microwave Integrated Circuits was organized by B. T. Vincent (Electro-Data, Inc., Garland, Texas). Panel members were J. B. LaGrange (Air Force Avionics Laboratory), *Chairman*; J. F. Bunker (MA); P. Clar (Motorola); R. B. Schilling (RCA); C. C. Snellings (TI); K. Sodomsky (BTL); and G. E. Bodway (HP).

Much of the discussion during this session was concerned with circuit types and components presented in papers in the regular Microwave Integrated Circuit Sessions. Jim Bunker and Phil Clar discussed the tradeoffs involved in using thick film versus thin film for production with general but clearly qualified conclusions that thick film would be more economical for large production runs. Ron Schilling covered production of lumped circuit elements; Cliff Snellings discussed some of the problems encountered in the MERA module production. Ken Sodomsky's presentation demonstrated the thoroughness with which high-reliability and tight-tolerance circuit elements must be treated. George Bodway discussed production of YIG-tuned oscillators built on sapphire, reporting very high yields of approximately 90 percent for production of the complete oscillator. Session attendance was approximately 250.

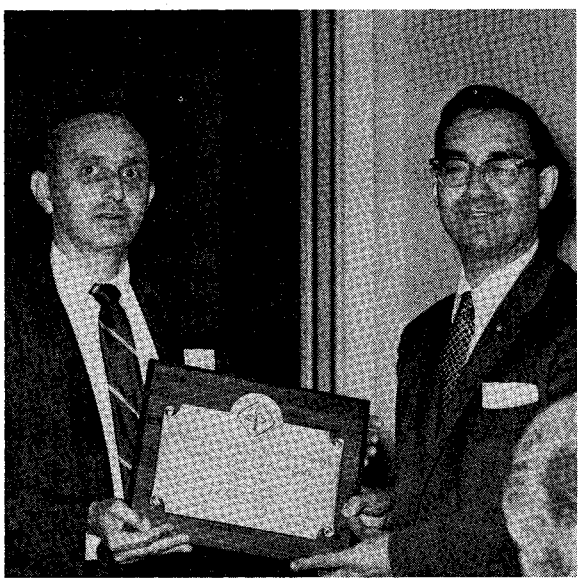
Evening Session III, Noise in Solid State Devices and Systems, was organized by K. E. Gsteiger of Sperry Rand Corporation, Clearwater, Fla. Panel members were J. R. Ashley (University of Colorado), *Chairman*; J. G. Josenhans (BTL); D. E. Wunsch (Collins Radio); K. E. Gsteiger (Sperry); T. R. Turlington (Westinghouse); J. F. White (MA); and R. A. Campbell (Raytheon). Chairman Ashley opened the session by defining part of the vocabulary used in noise discussions, after which he compared noise performance of a number of *X*-band noise sources, and described the usual noise measurements. Kurt Gsteiger presented some recent data on avalanche diode oscillators including multiple diode structures, Si, Ge, and GaAs diodes, and an injection phase lock experiment. Joe White gave an account of recent circuit improvements for Gunn oscillators and the reduction of FM noise achieved by careful circuit coupling design. Dave Leeson gave data on multiplier chain sources. The next three speakers keyed their discussions to the use of solid-state sources in systems. Dick Campbell covered requirements in pulsed radars, Tom Turlington discussed the importance of the FM noise spectrum in a multifunction radar, and Dave Wunsch discussed the effect of oscillator noise in multi-hop microwave communication systems. In the final talk Jim Josenhans reviewed the agreement between predicted and measured noise in avalanche diode oscillators, and made a guarded prediction that GaAs devices should have the lowest noise output. An estimated 230 attended the session. It was recommended by the panel that another session on noise be held at the 1970 G-MTT Symposium.

Banquet

On Tuesday evening 324 attendees were present at the annual Symposium banquet. The banquet was opened by Irv Solt, Master of Ceremonies, after which Howard Oliver, Dallas IEEE Section Chairman, extended a welcome to all.

ADCOM Chairman Leo Young presents Chairman Pins to past ADCOM Chairmen. *Left to right:* T. S. Saad (1959), A. A. Oliner (1960), S. B. Cohn (1963), Leo Young, D. D. King (1964), E. N. Torgow (1966), S. W. Rosenthal (1967), R. E. Henning (1968), Ben Warriner (1953). *Not shown:* A. G. Clavier (1954), W. W. Mumford (1955), A. C. Beck (1956), H. F. Engelmann (1957), W. L. Pritchard (1958), Kiyo Tomiyasu (1961), T. N. Anderson (1962), H. M. Altshuler (1965).

ADCOM Chairman Leo Young presents the Microwave Prize to W. F. Gabriel.



1968 ADCOM Chairman R. Henning presents the 1968 National Lecturer Award to Leo Young.

Ben Hallford and John Horton recognized the many contributors to the Symposium. Next on the program was the presentation of Chairman Pins to past ADCOM Chairmen by Leo Young. The first to receive his pin was Ben Warriner, organizer and first ADCOM Chairman, who described some of the trials and tribulations experienced in the formation of G-MTT. Leo Young then presented the Microwave Prize to W. F. Gabriel for his paper entitled "Tunnel Diode Low-Level Detection," published in the October, 1967, issue of the IEEE TRANSACTIONS ON MICROWAVE THEORY AND TECHNIQUES. The last award was made by Rudy Henning when he presented the 1968 G-MTT National Lecturer plaque to Leo Young. B. F. (Sandy) Coggin was then introduced as the featured banquet speaker. He gave a dynamic talk on the history, the importance, and the exciting and challenging future to be expected from space exploration.

TECHNICAL SESSIONS

The 96 technical papers were divided into twelve sessions. Twelve of these papers were late news items and do not appear in the Symposium Digest. These papers are listed here for the record.

Late News Items

Session MAM-I: Microwave Integrated Circuits I

"A Dynamic H-E Mode Solution for Microstrip," E. J. Denlinger (M.I.T. Lincoln Laboratory, Lexington, Mass.)

"Recent Tests of the MERA Radar," E. V. Farinholt and L. J. Hardeman (Texas Instruments Inc., Dallas, Tex.)

Session MPM-I: Ferrite Components

"A Periodically Loaded, Latching, Nonreciprocal Ferrite Phase Shifter," W. A. Spaulding (U. S. Army Missile Command, Redstone Arsenal, Ala.)

Session MPM-II: Solid-State Circuits and Devices

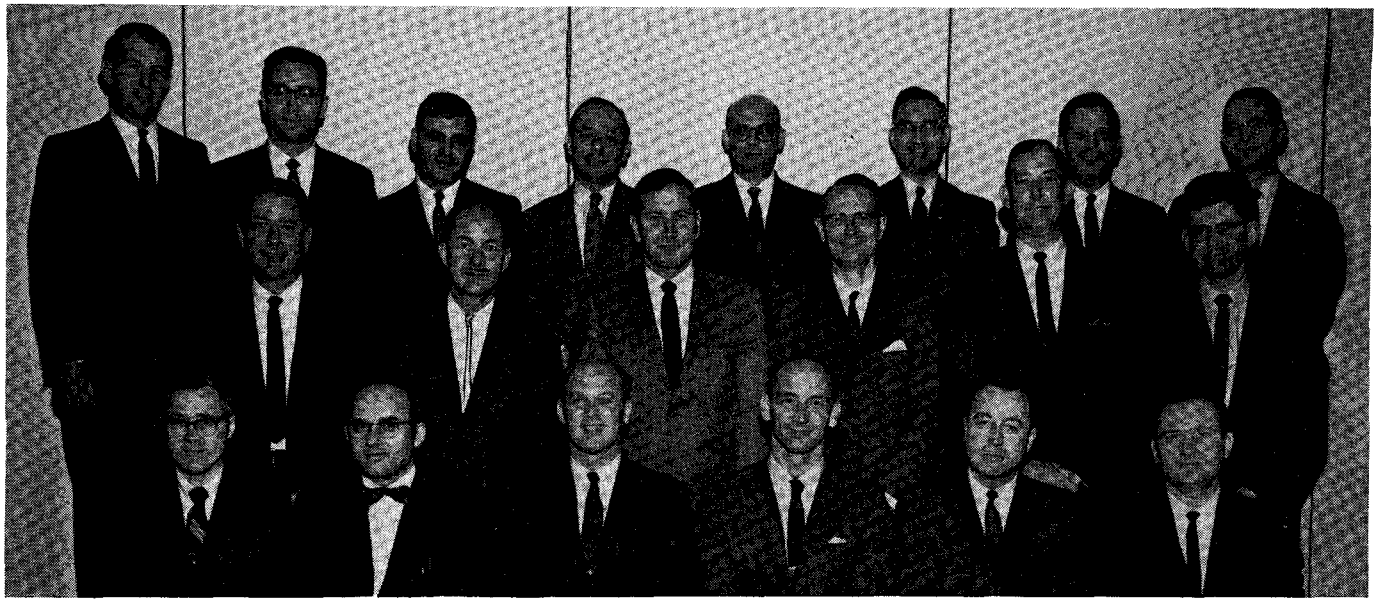
"Computer Simulations of LSA Relaxation Oscillators," B. I. Jeppsson and P. Jeppesen (Cayuga Associates, Inc., Ithaca, N. Y.)

"High-Power *L*-Band Gunn Sources," F. B. Fank, A. McEuen, W. Stein, and A. Vane (Varian Associates, Palo Alto, Calif.)

"RF Burnout in Point-Contact and Schottky-Barrier Diodes," Y. Anand and C. Howell (Microwave Associates, Inc., Burlington, Mass.)

Session TPM-I: Avalanche Diodes

"Small-Signal Parametric Effects and the High-Efficiency Mode in IMPATT Diodes," M. Grace (Sperry Rand Re-



Technical Program Committee. *First row, left to right*: W. J. Getsinger, E. Stern, B. Hershenov, B. T. Vincent, J. E. Pippin, J. B. Horton, *Chairman*. *Second row*: R. H. DuHamel, R. W. Beatty, A. Clavin, D. D. King, G. R. Harrison, R. D. Hall. *Third row*: G. P. Rodrigue, B. C. DeLoach, G. I. Haddad, M. Gilden, H. Sobol, L. Young, S. B. Cohn, M. C. Horton. *Not shown*: R. R. Webster, F. R. Arams, T. M. Hyltin, W. W. Mumford, S. Okwit, F. Clark, P. J. B. Clarricoats, M. M. Brady, K. Garbrecht, M. Uneohara.

search Center, Sudbury, Mass.)

"A Multiple-Diode High-Average-Power Avalanche-Diode Oscillator," C. T. Rucker (Sperry Rand Corporation, Clearwater, Fla.)

Session TPM-II: Passive Components

"Methods for Increasing the Directivity and Improving Flatness of Coupling Curves of Multisection Stripline Couplers," A. Alford (Alford Manufacturing Company, Winchester, Mass.)

Session WAM-I: Microwave Acoustics

"Bulk Wave Microwave Acoustics and Practical Applications," W. A. Crofut (Andersen Laboratories, Inc., Bloomfield, Conn.)

"Electron Beam Fabrication of High Frequency Surface Acoustic Wave Transducers," A. N. Broers, E. G. Lean, R. V. Pole, M. Hatzakis, D. Cullum, and C. G. Powell (IBM Watson Research Center, Yorktown Heights, N. Y.)

Session WAM-II: Computer-Oriented Microwave Techniques

"Hybrid Simulation of an Electrical Transmission Line at Radio Frequencies," J. P. Landauer (Electronic Associates, Inc., West Long Branch, N. J.) and M. Kurland (Newark College of Engineering, Newark, N. J.)

Microwave Integrated Circuits I

This session, chaired by B. T. Vincent, featured fundamentals and applications of microwave integrated circuits. Further insight into microstrip wave propagation was given in a paper by G. Zysman and D. Varon, and a late news item paper by E. Denlinger. A novel quadrature coupler on microstrip was described by J. Lange in the next paper. D. Adams and R. Ho then presented a paper on potential solutions to the problem of obtaining high-Q circuit elements through active filters and other applications of inverted common collector transistor circuits. The session was rounded out with papers on a 3–10 GHz mixer by R. Blight, a digital phase shifter by R. Lee and K. Sodomsky, an interesting and well-presented description of a multistage 4-GHz transistor amplifier by K. Ayaki, and a late news item by L. J. Hardeman and E. V. Farinholt on recent performance of the MERA solid-state radar.

Precision Measurements and Components

This session, chaired by R. W. Beatty, featured a wide range of techniques from measurements on microwave integrated circuits to computer-aided microwave impedance measurements. A paper by M. Caulton, B. Hershenov, L. S. Napoli, and S. P. Knight covered measurements of small lumped elements and characteristics of microstrip transmission lines at frequencies up through 18 GHz. Measurement of dielectric constant and loss tangent in balanced stripline using resonance techniques was the subject of the next paper by J. H. Ball, M. Olyphant, and L. D. Van Dover. W. F. Crosswell and J. E. Jones next presented a paper on measurement of dielectric constant and loss tangent on spacecraft thermal protection materials. A paper by F. S. Coale and W. L. Wallick on a high-power rotary slot attenuator featured the high-power capability of this type of rotary wave attenuator. The last two papers returned to measurement techniques. R. S. Hawke presented a nanosecond measurement technique for determining conductivity and permittivity of dielectric and semiconductor materials using a reflectometer bridge at 35 GHz. The final paper by J. E. Dalley dealt with the use of a general-purpose computer to remove system errors when using a manually operated network analyzer.

Ferrite Components

This session, chaired by J. E. Pippin, opened with a paper by J. C. Hoover and R. E. Tokheim describing a new type of four-port YIG filter. S. Okamura and T. Nagai then presented a novel technique for building small-size high-power

VHF (105 MHz) and UHF (450 MHz) circulators. D. H. Temme *et al.* next presented a paper describing a technique for building a low-cost latching-waveguide ferrite phase shifter. The following five papers dealt with planar ferrite configurations and began with an invited paper by G. P. Rodrigue on the present state of the art of planar ferrite devices. Next were two papers on slot line. The first paper, by E. Mariani *et al.*, concerned measurements on slot line. G. H. Robinson and J. L. Allen next presented the results of some recent work on slot line components, particularly phase shifters. C. P. Wen then presented a technique for building planar ferrimagnetic resonant isolators using coplanar waveguide at 6 GHz. R. H. Knerr concluded the papers on planar ferrites with his presentation on a thin-film lumped-element 1.2-GHz circulator. A paper concerning a six-port ferrite switch by A. I. Gehm, Yu. P. Kasianov, and N. V. Slavin of the USSR was not presented for unknown reasons. The session was concluded with a late news paper by W. A. Spaulding who presented a novel design for a periodically loaded latching phase shifter.

Solid-State Circuits and Devices

F. K. Clark served as Session Chairman. The session was opened with a paper by A. I. Grayzel and M. Minkoff which described a technique for varactor multiplier stabilization without ferrite isolators. A second paper on multipliers by K. Kotzebue and G. Matthaei described techniques for building an octave bandwidth doubler. The session program next turned to high-power solid-state work featuring a paper on the study of pulsed LSA GaAs diodes by B. I. Jeppsson, a 1000-watt CW UHF amplifier described by R. Bailey, W. Bennett, L. Heckman, and I. Martin, and a 10-MW radar duplexer described by J. J. Wormser. These papers were augmented by three late news items. B. I. Jeppsson and P. Jeppesen presented a film based on computer simulation of an LSA relaxation oscillator; F. B. Bank *et al.* presented some recent achievements in power output obtained using GaAs diodes; and Y. Anand and C. Howell reported new data on burnout of Schottky barrier mixer diodes in a pulsed radar. This session was particularly popular with attendance of 350+.

Gunn-Effect Devices

This session, chaired by R. D. Hall, opened with an invited paper by L. F. Eastman on the state of the art of Gunn-effect devices. D. D. Khandelwal and W. R. Curtice then presented a paper on a quenched-domain mode oscillator, and M. Omori discussed some of the problems encountered in design of a YIG-tuned Gunn oscillator. S. E. Gibbs rounded out the first half of the session with a comprehensive paper on temperature effects on LSA oscillations between 26 and 40 GHz. Next, S. Mitsui and A. Kondo presented a technique for fabricating composite Gunn diodes, and M. Stringfellow, G. Bednar, F. S. Rosenbaum, and K. L. Horn described an array transmitter built using phase-locked Gunn oscillators. W. C. Tsai and F. J. Rosenbaum completed the session with a paper on amplitude and frequency modulation of wideband tunable Gunn oscillators operating at *X*-band.

Millimeter-Wave Components

During this session, chaired by D. D. King, the confluence of microwave and optical techniques showed clearly. Two excellent contributions to filters represented the two approaches. From the microwave side, S. Shimado described TE_{01} mode band-splitting filters using figure-eight hybrids. G. Matthaei presented the quasi-optical approach in his paper featuring a reflecting-beam waveguide structure with parallel-plate reflectors. D. Anderson clearly demonstrated the synthesis of optics and microwaves in his discussion of an infrared parametric up-converter. Other papers presented were an invited paper on detection by F. Arams (presented by J. J. Taub), an invited paper by I. Kaminow on light modulators, a paper on detection by paramagnetic materials presented by C. F. Krumm, and a survey of some recent developments of millimeter-wave components by M. Cohn, L. Dickens, and J. Dozier. A paper by A. W. Snyder on a perturbation theory for dielectric and optical waveguides was not presented because of problems encountered in travel arrangements for the author. The overall conclusion drawn from the papers presented is that both microwave and optical techniques will contribute to the exploitation of the millimeter and infrared regions.

Avalanche Diodes

G. I. Haddad served as Chairman for the session. The enormous popularity of this session was illustrated by the large number of questions and very lively discussion following each paper. Nine papers were presented including two late news items. Four papers concerned the high-efficiency mode of operation. The first paper, by W. J. Evans, was invited and dealt with the circuit aspects of the high-efficiency mode. Next, B. Hoefflinger described the properties of an amplifier in this mode of operation, S. G. Liu presented results obtained in the high-efficiency mode in microstrip circuitry, and M. Grace described some further operating characteristics and circuits of the same mode. Two papers on multiple diodes for high-power generation were presented. J. Sie described a four-diode source with 1-watt CW output, and C. Rucker presented a very interesting scheme whereby approximately 5-watts CW was obtained with five diodes in parallel. The session was rounded out by a paper by C. Dunn and J. Dalley on characterization of IMPATT diodes using a network analyzer and computer, the description of a mixer/oscillator and its performance using a YIG-tuned avalanche oscillator by W. B. Day and W. M. Jones, and an analysis of a broad-band negative resistance oscillator by K. Kurokawa, J. Beccone, and N. D. Kenyon.

Passive Components

This session, chaired by S. B. Cohn, was concerned with filters during the first half and general microwave networks in the second half. R. Levy opened the session with a paper on filter synthesis for rejection of harmonics. R. Livingston then presented a paper on predistorted filter design. Next, three papers were presented on elliptic function filters. J. Rubinstein, R. L. Sleven, and A. F. Hinte described a 1-percent bandwidth microstrip design, and J. D. Rhodes de-

scribed the design of a 30-percent bandwidth cavity-coupled design. The third paper was a late news paper by A. Alford on a novel technique for improving directivity of multisection stripline couplers. The second half opened with a theoretical paper by W. Steenaart and R. J. Murphy on commensurate transmission-line circuits. A. Podell then presented a paper on a 3-octave ring magic T, and E. W. Carpenter presented a paper on a 6:1 bandwidth stripline magic T using the 8.34-dB tandem coupler technique. The session was completed by two papers on coupled transmission lines—the first by J. I. Smith on coupled lines in suspended substrate, followed by a presentation on coupled lines in inhomogeneous dielectric by A. K. Johnson and G. I. Zysman.

Microwave Acoustics

This session was chaired by G. P. Rodrigue.

The applicability of an acoustics session in a microwave symposium was clearly demonstrated by two invited papers —B. A. Auld's paper covering acoustic wave analysis using microwave concepts, and E. Stern's review of the state of the art on microsound technology. E. G. Lean's late-news presentation on a recent breakthrough in reducing insertion loss in transducers was an excellent complement to Stern's review. The survey of microwave acoustic technology was rounded out by a review of bulk wave acoustics by W. A. Crofut. P. H. Carr, A. J. Slobodnik, and J. C. Sethares then presented some results of measurements on surface wave propagation on $LiNbO_3$ and discussed surface waves on saturated magnetic substrates. A paper by D. A. Bozanic *et al.* concerning electron paramagnetic resonance signal storage in irradiated quartz was followed by A. J. Bahr's presentation on active impedance matching elements for acoustic delay lines. Bahr's paper was somewhat complementary to an earlier paper on active networks by D. Adams and R. Ho presented in the Microwave Integrated Circuit session. The session was rounded out by a paper by H. A. Heynau and M. J. Brienza on a continuously variable delay line using laser–acoustic interaction, and a paper by W. Bongianni, J. Collins, and F. Pizzarello on surface wave propagation using YIG films grown on gadolinium gallium garnet.

Computer-Oriented Microwave Techniques

This session, chaired by W. J. Getsinger, was concerned with two general problem areas—application of computer techniques to microwave circuit problems and solution of electromagnetic field problems. In the first half of the session, J. W. Bandler and R. A. MacDonald presented their work on a new optimization method leading to equal-ripple performance for microwave networks. Next presented were papers by S. Mahdi and A. Macnee on synthesis of transmission line networks, T. Houston and L. Read on amplifier design, and J. B. Castillo and L. E. Davis on simulation of circulators, all based on new computer-oriented design approaches. The second-half of the session began with a review by A. Wexler of new mathematical techniques used in solving electromagnetic field problems. Following Wexler's paper were three papers on specific examples of EM boundary-value problems. E. G. Cristal presented methods for solving TEM field problems, C. P. Bates discussed intermodal coupling between straight and continuously curved waveguide, and W. H. Otto (substituting for G. K. Campbrell) discussed vector field boundary problems. A late news paper, by J. P. Landauer and M. Kurland, described techniques for using the hybrid computer for microwave problems. The diversity of subject matter in this session demonstrated that the computer has entered and changed nearly all areas of microwave engineering.

Microwave Integrated Circuits II

This session was chaired by H. Sobol, and featured microwave integrated circuit systems.

The session opened with two papers on parametric amplifiers. R. S. Foreman presented a talk on a fully integrated 2.25-GHz paramp, followed by a similar talk by Bura, Pan, and Yuan on three slightly different configurations of amplifiers at 1.8, 2.25, and 3.5 GHz. J. J. Dupre next presented an excellent paper on an oscillator–amplifier combination using sapphire substrate and a YIG tuning element. M. M. Hower and K. F. Sodomsky presented a paper concerned with an extremely reliable, tight specification amplifier. D. Staiman and M. Breese then discussed a 200-watt-peak pulsed UHF transistor amplifier designed using eight unit amplifiers in parallel. The final paper was presented by J. C. Pinac and B. S. Skinner and featured the design of an FM telemetry transmitter and command receiver operating at 2.2 to 2.3 GHz. In general, the papers in this session complemented the two earlier sessions on microwave integrated circuits and demonstrated some of the advantages to be achieved by using microwave integrated circuits for system design.

Millimeter-Wave Systems

J. W. Dees substituted as Chairman for J. C. Wiltse. This session was the second of two sessions on millimeter waves and featured many of the experimental programs using millimeter-wave frequencies. F. R. Seyfried presented the opening paper, discussing theoretical and experimental values of phase constant for dipole wave propagation in gyromagnetic ferrite rod. Three papers dealt with radiometric studies and hardware. F. I. Shimabukuro described radio maps of the sun at 94 GHz; K. Richer presented a paper on techniques for near earth scanning of ground targets and moving vehicles; W. Copeland described system applications including detection of ships at sea at 35 GHz. Two other papers dealt with millimeter wave radar investigations. L. A. Hoffman described a 94-GHz radar for precise measurement of the spin rate of spinning satellites, and Marion Foral described a 94-GHz radar which is used to detect exhaust of a jet aircraft and a cannon blast, among other things. There was an approximate attendance of 200 at the session.