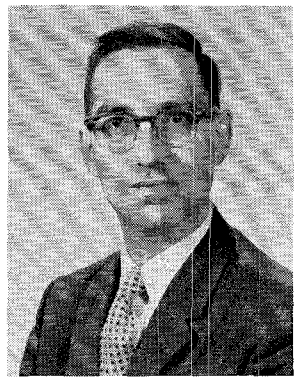
PTGMTT International Symposium

International Hotel, John F. Kennedy International Airport at Idlewild, Long Island, N. Y.
May 19—21, 1964

S. ROSENTHAL
Chairman, Steering Committee

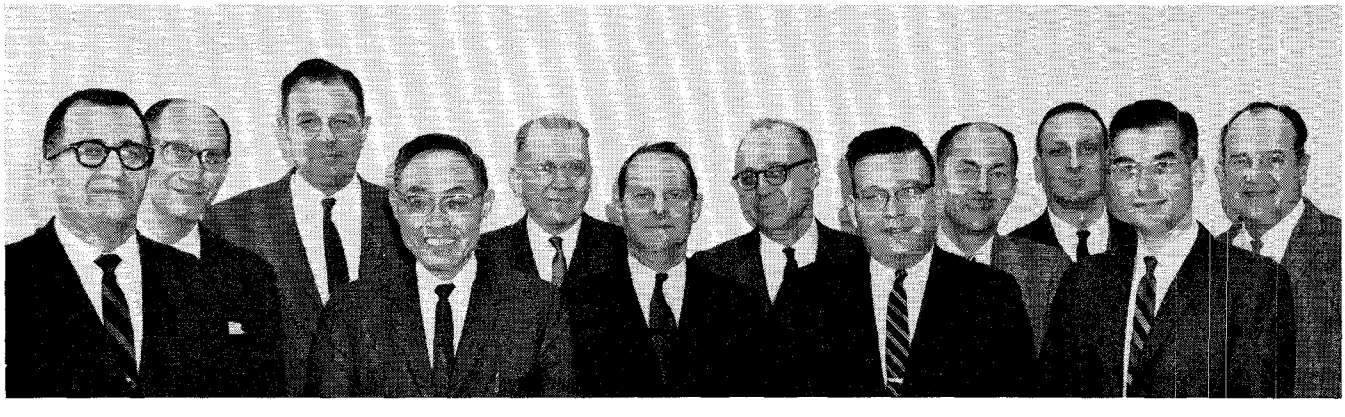
E. G. FUBINI
Banquet Speaker

E. WEBER
Keynote Speaker



L. YOUNG
Microwave Prize

Steering Committee (*left to right*) B. Aaron, H. Altschuler, L. Forker, L. Swern, E. Torgow, S. Rosenthal, G. Shapiro, M. Chomet, H. Bachman and N. Spencer. *Below*, Technical Program Committee (*left to right*) T. Saad, S. Rosenthal, B. Aaron, K. Tomiyasu, H. Wheeler, M. Lebenbaum, H. Jasik, L. Swern (*Chairman*), R. Beatty, W. Kahn, A. Oliner and W. Mumford.



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REGISTRATION

Advanced registration may be made by completing the registration form attached to the Advance Program Booklet and returning it with appropriate payment to

1964 PTGMTT International Symposium
Polytechnic Institute of Brooklyn, Long Island Graduate Center
Route 110
Farmingdale, N. Y.

Checks should be made payable to the 1964 PTGMTT International Symposium. Registration forms must be postmarked before May 4 to qualify for the advance registration rate.

The advance registration rates are

IEEE	STUDENT	NON-IEEE
$6.00	$2.00	$8.00

The registration rates after May 4 are

IEEE	STUDENT	NON-IEEE
$8.00	$2.00	$10.00

The registration desk will be open on Monday, May 18, from 10:00 A.M. to 6:00 P.M., in the Main Lobby of the International Hotel and thereafter in the Foyer of the Starlight Gardens during the following hours:

Tuesday, May 19—8:00 A.M. to 6:00 P.M.
Wednesday, May 20—8:00 A.M. to 6:00 P.M.
Thursday, May 21—8:00 A.M. to 2:30 P.M.

TRANSPORTATION

Visitors to New York arriving by air at the John F. Kennedy International Airport may use the courtesy limousines available from the International Hotel by dialing 59092 on the airport direct service telephone. Those arriving at LaGuardia Airport may call the hotel direct by dialing 995-9000 for the courtesy limousine. From midtown airlines terminals, Carey Transportation bus service direct to the hotel is available. Advise the bus driver of your intended destination. From Pennsylvania Station, take the Long Island Railroad to Jamaica Station where taxi cabs or Carey buses to the International Hotel are available.

Free parking will be available for all symposium attendees at the rear parking lot of the International Hotel.

HOTEL ACCOMMODATIONS

Requests for reservations at the International Hotel should be made on the registration form. These will be handled on a "first come, first served" basis. Confirmation of reservations will be sent to you by the hotel. Attendees who desire other accommodations must make their own reservations with the hotel of their choice. Due to the influx of visitors expected in the Long Island-New York area as a result of the World's Fair, those wishing other accommodations should make early reservations.

TECHNICAL SESSIONS

All sessions of the symposium will be held in the Starlight Gardens of the International Hotel. There are no simultaneous sessions.

SPECIAL EVENTS

A Gabfest will take place on Monday evening, May 18 from 8:30 to 10:00 P.M. in the Flight Bar of the International Hotel. This will be an informal gathering of those wishing to renew acquaintances.

A visit to the World's Fair has been arranged for symposium registrants on Tuesday evening, May 19. Buses will leave from the Starlight Gardens entrance at 8:00 P.M. Reduced rate tickets, including transportation to and from the World's Fair site, will be available.

COCKTAIL PARTY AND BANQUET

Cocktail Party

Advance Registration	After May 4
$2.50	$2.75

Banquet

Advance Registration	After May 4
$9.00	$10.00

A cocktail party will be held prior to the symposium banquet on Wednesday, May 20, at 6:00 P.M. in the reception area of the Starlight Gardens of the International Hotel. The symposium banquet will be held in the Starlight Gardens at 7:00 P.M. The Master of Ceremonies for the banquet will be William W. Mumford of the Bell Telephone Laboratories. An entertaining musical satire by Dr. Morris Ettenberg will be presented under the author's direction. The banquet speaker will be Dr. Eugene G. Fubini, Assistant Secretary of Defense—Deputy Director of Defense Research and Engineering. The topic of Dr. Fubini's talk will be announced at the banquet.

MICROWAVE PRIZE AWARD

The 1963 Microwave Prize will be awarded on May 20, 1964, at the symposium banquet, to Dr. Leo Young of the Stanford Research Institute, Menlo Park, Calif., for his very significant contributions to the field of microwave in his paper entitled "Direct-Coupled Cavity Filters for Wide and Narrow Bandwidths," published in the May, 1963 issue of these TRANSACTIONS, and for other papers in IEEE publications. Presentation of the award will be made by Dr. D. D. King, Chairman, PTGMTT National Administrative Committee.

SYMPOSIUM DIGEST

A copy of the Symposium Digest will be distributed to each registrant. Additional copies may be purchased at the registration desk at $3.00 per copy.

LADIES' ACTIVITIES

An interesting Ladies' Activities Program has been arranged. The Tuesday program will consist of a tour of the United Nations, and will include lunch in the Delegates' Dining Room. On Wednesday the ladies will attend two television broadcasts. Lunch and shopping tours to follow the broadcasts are being planned. The Thursday Program will consist of a visit to the World's Fair. All ladies' tours will assemble, at times yet to be designated (approximately 9:00 A.M.), in the Hospitality Room of the International Hotel. A detailed schedule will be available at the Registration Desk. A single moderate fee will cover all transportation and admission fees; the cost of meals is not included. Tours will return to the International Hotel no later than 4:30 P.M. daily.

TECHNICAL PROGRAM

Starlight Gardens

International Hotel

Tuesday, May 19, 1964

9:30–10:00 A.M.

Introductory Session

Welcoming remarks: S. W. Rosenthal, *Chairman*, Steering Committee, 1964 PTGMTT International Symposium; D. D. King, *Chairman*, PTGMTT National Administrative Committee.

Keynote address: E. Weber, *President*, Polytechnic Institute of Brooklyn, Brooklyn, N. Y., "The Era of Microwaves."

SESSION I—WAVEGUIDES

Chairman: L. Lewin, Standard Telecommunications Laboratories, Harlow, England

10:00–10:15 A.M.

"Characteristics of Log-Periodic Transmission Line Circuits," R. H. DuHamel and M. E. Armstrong, Hughes Aircraft Co., Fullerton, Calif.

The analysis of frequency-independent log-periodic hybrids, directional couplers, and phase-difference circuits includes the determination of the input reflection coefficient of a transmission line shunt and/or series loaded in a log-periodic manner by complex impedances. Ideally, complete reflection should occur and the phase of the reflection coefficient should vary linearly with the logarithm of the frequency. Results of an extensive investigation of a transmission line loaded with several types of impedances are presented.

10:15–10:25 A.M.

"Log-Periodic Phase Difference Circuits," R. H. DuHamel and M. E. Armstrong, Hughes Aircraft Co., Fullerton, Calif.

The constant phase difference circuits are composed to two symmetrical, two-port, log-periodic, transmission line circuits. The two-ports are matched and the phase shift through them is approximately a linear function of log f. By scaling one two-port circuit with respect to the other, an arbitrary phase difference between the coupled outputs may be achieved over theoretically unlimited bandwidths. Design concepts are discussed and the results of theoretical and experimental investigations are presented.

10:25–10:35 A.M.

"Log-Periodic Octaline Hybrid Junctions," R. H. DuHamel, M. E. Armstrong and M. A. Meyer, Hughes Aircraft Co., Fullerton, Calif.

The octaline circuits consist of eight radial transmission lines coupled together at log-periodic intervals by other transmission lines. Opposite radial lines are fed as balanced pairs so that the structure becomes a four-port function. With the proper choice of design parameters, the junction will perform as a magic T over theoretically unlimited bandwidths. An analysis of the circuit is presented and the results of theoretical and experimental investigations are reported.

10:45–11:15 A.M., Coffee Break
11:15–11:25 A.M.

"Band-Pass Filters with Steep Skirt Selectivity," E. N. Torgow and P. D. Lubell, Dorne and Margolin, Inc., Westbury, N. Y.

High Q band-pass filter performance can be realized with relatively low Q resonators when band reject filter sections are used to augment the characteristics of the basic band-pass filter. The techniques described result in a filter whose cutoff characteristics are extremely sharp while pass band insertion loss remains low. Analysis has demonstrated that filter sections connected through appropriately phased lengths of line will not interact to produce spurious transmissions. Measured performance characteristics of composite band-pass filters verify the predicted results.

11:30–11:45 A.M.

"Application of Exact Synthesis Methods to Multichannel Filter Design," R. J. Wenzel, Bendix Corporation, Southfield, Mich.

An exact synthesis procedure is presented for microwave TEM mode lowpass-highpass filter pairs applicable to the design of multichannel filters. Requiring the filters to be complementary allows a perfect match to be obtained at the inport. Criteria for obtaining steeper crossover characteristics by relaxing the input match requirement are obtained by use of Hilbert transforms. The networks obtained are synthesized exactly and lead to structures with responses that can be specified over wide frequency bands.

11:50 A.M.–12:00 NOON

"Circular Waveguide Loaded with Dielectric Discs for Increased Usable Bandwidth," P. J. Meier, M. A. Balfour and H. A. Wheeler, Wheeler Laboratories, Great Neck, N. Y.

The useful (single-mode) bandwidth of circular waveguide may be greatly increased by using a smaller diameter with periodic loading by discs of high dielectric constant. The waveguide diameter is chosen small enough to cut off the second (TM-01) mode, and dielectric discs are inserted to load the dominant (TE-11) mode, so that it can propagate. The discs have little effect on the TM-01 mode. By this means, the ratio of the TM-01 cutoff frequency over the TE-11 can be greatly increased from its usual value of 1.31; then the principal limitation becomes the TE-21 mode which propagates at frequencies over 1.66 times the TE-11 cutoff. Restricting operation to frequencies over 1.20 times the TE-11 cutoff, the disc loading enables a 4-fold increase in the useful bandwidth. Dielectric-disc loading offers advantages for various components in circular waveguide, especially rotary joints and array radiators.

12:05–12:20 P.M.

"Properties and Applications of the TM_{11} Mode in Cylindrical Disc-Loaded Waveguide," O. H. Altenmueller, R. R. Larsen, and G. A. Loew, Stanford University, Stanford, Calif.

Whereas the TM_{01} mode in a cylindrical disc-loaded waveguide can be made to exert a cumulative longitudinal force on charged particles (used in traveling-wave tubes and linear accelerators), the TM_{11} mode is shown to yield a force transverse to the direction of propagation. This paper describes the microwave properties of the TM_{11} mode in disc-loaded structures and its interaction with charged particle beams. Several practical applications are described including multi-Bev particle separators, bunch analyzers, beam position monitors, and an explanation for the beam "blow-up" or "pulse shortening" phenomenon observed in linear electron accelerators.

12:25–12:40 P.M.

"Periodic Waveguide Structures Containing Ferrimagnetic Material," P J. B. Clarricoats and M. I. Sobhy, University of Leeds, Leeds, England.

In the paper, theoretical dispersion curves are obtained for a number of circularly cylindrical periodic structures containing axially magnetized ferrimagnetic material. Such structures could be used in traveling-wave amplifiers and backward-wave oscillators. Certain of the results suggest that a very wide tuning range could be achieved for a backward-wave oscillator if the beam velocity and magnetic field were to be simultaneously adjusted. The structures could also be used as a basis for a magnetically-tuned band-pass filter, and attenuation characteristics are presented for such a structure.

SESSION II—FERRITES

Chairman: S. Okwit, Airborne Instruments Laboratory, Deer Park, N. Y.

2:30–2:45 P.M.

"A Theory for the Operation of the Tetrahedral Junction Ferrite Switch," I. Bardash, Radio Corporation of America, Moorestown, N. J.

A theory for the operation of the tetrahedral junction ferrite switch is offered. Propagation in ferrite media and asymmetric waveguide structures is considered and related to the behavior of the switch. Perpendicular HE modes (modes with longitudinal H and E fields) are induced by the application of a longitudinal dc magnetic field to the ferrite rod. In the presence of a guiding system whose orthogonal modes have different propagation velocities, these perpendicular HE modes are alternately converted from linearly to circularly and back to linearly polarized waves very much like cascaded quarter-wave plate sections. When this condition exists, propagation through the switch occurs. Experimental results for sixteen different switch configurations are presented. Measurements were made in the C-band frequency range.

2:50–3:05 P.M.

"On the Theory of the Ferrite Junction Circulator," C. E. Fay and R. L. Comstock, Bell Telephone Laboratories, Murray Hill, N. J.

The operation of the stripline Y-junction circulator is explained in terms of a splitting of the resonance of the center-disc structure which results in a standing wave pattern that can be rotated so that two of the ports are coupled and the third port isolated. The expressions for the fields of the structure are developed and the relations which produce the desired orientation of the standing wave pattern are given. An experimental mode chart of the circulator structure shows the relations of the various modes and the points where circulation occurs. E-field probe measurements confirm the existence of the postulated standing wave pattern. Extension of the theory to the waveguide Y circulator is suggested.

3:10–3:20 P.M.

"Circulator Synthesis," J. A. Weiss, Lincoln Lab., Lexington, Mass. and Worcester Polytechnic Institute, Worcester, Mass.

A symmetrical three-port ring network composed of reciprocal T junctions and nonreciprocal phase shifters is analyzed theoretically to determine under what conditions it exhibits perfect circulation. All physically realizable T junctions are considered. It is found that many such junctions, combined with appropriate phase shifters specified by the theory, form perfect circulators. Among these are many cases for which the internal wave amplitudes are small, and which require only very small amounts of nonreciprocal phase shift. The relevance of the model to existing circulator designs and to novel designs incorporating improvements in bandwidth and other characteristics will be discussed.

3:25–3:35 P.M.

"A Symmetrical, Distributed-Constant Circulator," R. W. Roberts, Melabs, Palo Alto, Calif.

A circulator is described, consisting of a three-phase, three-wire line with a ferrite element symmetrically disposed in the region between the wires. A ground shield is placed around the entire structure. This device has both the symmetry properties of the junction circulator and the distributed interaction region common to the differential phase shift and Faraday rotation types of circulators.

3:40–4:10 P.M., Coffee Break

4:10–4:25 P.M.

"Phonon Generation at 70 kMc," J. B. Thaxter and P. E. Tannenwald, MIT Lincoln Laboratory, Lexington, Mass.

Phonons have been generated for the first time at 70 kMc. The acoustic wave is generated by the piezoelectric effect in a quartz rod placed in the high electric field region of a re-entrant cavity, which is excited by a pulsed magnetron. A superheterodyne receiver detects a series of phonon echoes produced by multiple reflections of the acoustic wave in the quartz rod. Data have been obtained showing the temperature dependence of the relative phonon attenuation in quartz from 4.2° to 25°K. As expected, the attenuation at 70 kMc is larger than at 24 kMc but similar in shape to the well-known attenuation curves at lower microwave frequencies.

4:30–4:45 P.M.

"Properties and Excitation of Spin Waves—A New Microwave Time Delay Medium," I. Kaufman and R. Soohoo, Space Technology Laboratories, Redondo Beach, Calif.

This paper essentially contributes the following two new pieces of information to spin wave technology:

1) It demonstrates that the ratio of electric to magnetic field intensity in spin wave propagation is a very large number. This is a disagreement with existing information.
2) It discusses a new type of electromagnetic-to-spin wave transducer.

The paper begins with a discussion of the reason for the interest in spin waves as microwave time delay media and of the nature of spin waves. This is followed by the electric and magnetic field treatment, above. The material on the transducer will be preceded by a discussion of the general problem of spin wave excitation. Numerical values of some of the parameters of interest will be presented.

4:50–5:05 P.M.

"A Two-Port Microwave Variable Delay Line," F. A. Olson and L. D. Buchmiller, Microwave Electronics Corp., Palo Alto, Calif.

This paper describes the operation of a two-port electronically-variable delay line utilizing pure spin wave propagation in single-crystal yttrium iron garnet. Particular advantages of this device are transmission-type operation, delay continuously variable from zero to several microseconds by means of magnetic field and no critical dimensions or surface finishes. This form of delay, as well as those due to acoustic-wave and spin-wave/acoustic-wave propagation, has been observed at frequencies from 1 Gc to 10 Gc. A comparison of the performance of these delay processes with particular attention to insertion loss, bandwidth, frequency limits and delay range will be presented.

5:10 to 5:25 P.M.

"A YIG Delay Line for Use at Microwave Frequencies," R. A. Sparks, G. R. Gourley, and E. L. Higgins, Emertron-Litton, College Park, Md.

Recent experimental investigations of the microwave acoustic properties of single crystal yttrium iron garnet have suggested many novel RF device applications that should prove useful to the system designer. In this paper the results of using YIG bars for microwave delay lines up to 4 Gc/sec are discussed. Design considerations for light-weight, low-power, noncryogenic microwave memories are reviewed using yttrium iron garnet as the delay medium and permanent magnets for the biasing field.

Wednesday, May 20, 1964

SESSION III—LASERS AND MILLIMETER WAVES

Chairman: K. Tomiyasu, General Electric Co., Schenectady, N. Y.

9:00–9:15 A.M.

"A Novel Solid State Modulator for Millimeter Waves," A. Saeki, Y. Horiguchi and H. Tsuru, Nippon Electric Company, Kawasaki, Japan.

A new modulator is constructed by combining a crystal diode with a ferrite gyrator. The modulator is adapted to such high-speed operation as may not be attained by a conventional ferrite modulator and has such a high switching ratio as may not be achieved by a crystal diode modulator of a conventional transmission type. The modulation characteristics can be adjusted by controlling the magnetic field electrically. The modulators have been built at 24-Gc and 50-Gc bands. Switching ratios of 30 to 50 db are easily obtainable. The rise and decay times are apparently considerably less than 2 nsec.

9:20–9:35 A.M.

"A Technique for Measuring Phase Modulation or Rapid Phase Changes of a Microwave Signal," W. P. Ernst, Princeton University, Princeton, N. J.

The system takes advantage of the fact that a phase-modulated voltage will produce equivalent frequency modulation, *i.e.*, equivalent FM $= d(\Delta\theta)/dt$. The microwave carrier frequency is shifted in a single sideband generator to a frequency f_c+f_m. The upper sideband is passed through the medium which produces the phase modulation and then mixed with the original carrier f_c. The difference frequency f_m, contains the phase-modulation information. The signal is put through a limiter-frequency discriminator of center frequency f_m. The discriminator output voltage will be directly proportional to the time rate of change of the phase excursions. An integrating network ($E_0 \sim 1/f$) after the discriminator produces an output voltage which is directly proportional to the original phase modulation. Calibration is accomplished by imposing a known amount of phase modulation on the sideband modulating signal f_m and observing the system output signal. This system has been built in the 70-Gc band and is capable of following phase changes over microsecond periods.

9:40–9:55 A.M.

"Quasioptical Waveguide Filters," J. J. Taub, H. J. Hindin and G. P. Kurpis, Airborne Instruments Laboratory, Deer Park, N. Y.

Quasioptical structures that can be used to design filters in oversize waveguides are described. This technique is applicable at millimeter and submillimeter wavelengths. The types of filters considered are band-pass, low-pass, directional band pass, and directional low pass. A two-resonator band-pass filter operating at 9 mm, using circular hole gratings as coupling elements, was developed. It had a 22.5-Mc 3-db bandwidth and a center-frequency loss of 1.6 db. A directional low-pass filter consisting of four quarter-

wavelength slabs placed at the center of a junction of four waveguides was given a preliminary evaluation at 330 Gc; the results are encouraging.

10:00–10:15 A.M.

"Multiple Quantum Frequency Conversion in Extended Interaction Structures," D. J. Scalapino, A. Vassiliadis and R. N. Wilson, Kane Engineering Laboratories, Palo Alto, Calif.

In 1959, E. T. Jaynes suggested that a resonant, multiquantum process could provide an efficient method of frequency conversion at high frequency and high powers. This offers a means of generating millimeter waves using existing power sources in the *X* and *K*-band region. Theoretical results for traveling-wave structures in which multiquantum frequency conversion occurs over an extended interaction region are presented. Experimental confirmation of these results was obtained using an NH_3 filled coaxial line. Three-quantum conversion from 8.3 kMc to 24.9 kMc with the order 100 watts of power converted has been obtained. Five-quantum conversion processes have also been observed.

10:20–10:50 A.M., Coffee Break

10:50–11:20 A.M.

Invited Paper: "Detection and Demodulation of Laser Beams," A. Siegman, Stanford University, Stanford, Calif.

This paper will review some of the important devices and techniques available for optical reception, particularly in possible future optical communications systems. An exhaustive survey of all the existing or proposed photodevices will not be attempted. Rather, some instructive comments will be offered on such key topics as optical heterodyning; optical heterodyne receivers vs laser amplifier receivers; synthesis of special optical networks; and linear or coherent detection vs quantum counting.

11:30–11:45 A.M.

"Demodulation of Microwave Frequency-Modulated Light Using Birefringent Crystals," E. O. Ammann, Sylvania Electric Products, Mountain View, Calif., and S. E. Harris, Stanford University, Stanford, Calif.

Various methods of demodulating frequency-modulated light using birefringent crystals are discussed. Included are the birefringent discriminator, the optical ratio detector and multicrystal devices. All these devices demodulate FM by converting it to AM, whereupon conventional photodetectors can then be employed to demodulate the AM.

11:50 A.M.–12:05 P.M.

"Analysis of Negative-Resistance Photodiodes," M. Wright, Airborne Instruments Laboratory, Deer Park, N. Y.

This paper describes the theoretical performance of a junction photodetector in which a negative resistance also appears across the junction. An equivalent circuit is described which is applicable to the midband performance of parametric photodetectors, tunnel diodes, photodetectors and passive junction photodiodes. The available power is derived for the active devices, and the passive photodiode is shown to be a limiting case of the active detectors. A power gain is defined for active devices and high gain approximations are shown. The noise performance is given and the inadequacy of an equivalent resistance for active devices is pointed out. The preferred "NEP" noise performance is derived.

12:10–12:25 P.M.

"Macroscopic Single-Mode Waveguide for the Construction of Optical Components," D. W. Wilmot, Wheeler Laboratories, Great Neck, N. Y.

Many applications which have been proposed for laser radiation require sophisticated optical components which are as yet unavailable. To fill this need a novel optical waveguide of large size, operating in a single mode, has been developed and component configurations proposed. This waveguide is referred to as "macroscopic" to indicate that it is at least an order of magnitude larger than the wavelength of light. It is similar to the dielectric-slab waveguides known at microwave frequencies, and supports only the dominant mode. The components are analogous to conventional microwave devices such as balanced mixers and directional couplers. The theory and design of such a waveguide, with cross-sectional dimensions of 50 wavelengths, is discussed and the operation of an experimental model is illustrated.

SESSION IV—HIGH POWER

Chairman: S. W. Rosenthal, Polytechnic Institute of Brooklyn Graduate Center, Farmingdale, N. Y.

2:30–3:00 P.M.

Invited Paper: "High-Power Limitations of Microwave Control Circuits," L. Gould, Microwave Associates, Burlington, Mass.

3:10–3:25 P.M.

"High-Power Filters for the Suppression of Spurious Frequencies," L. Young, B. M. Schiffman and E. G. Cristal, Stanford Research Institute, Menlo Park, Calif., and O. Allen, Rome Air Development Center, Rome, N. Y.

The need to suppress radio frequency interference from high-power transmitters has given impetus to the development of new types of filter and the improvement of older types. The ideal filter might have the low stop-band VSWR and absorption property of the leaky-wave filter, the wide stop-band and compactness of the waffle-iron filter, and the simplicity of the short-slot directional-coupler harmonic pad. These and other types of high-power filters will be discussed and compared.

3:30–3:40 P.M.

"A DC Triggered High-Speed, High-Power Microwave Spark Gap Switch," H. Farber, M. Klinger, M. Sucher and E. Malloy, Polytechnic Institute of Brooklyn Graduate Center, Farmingdale, N. Y.

Operation of a microwave spark gap switch triggered with a short high voltage pulse is described. C-band power of 1-mw peak and 4-μsec pulse width was switched in less than ten nanoseconds at 100 pps with less than 0.3-db arc loss in air at atmospheric pressure. Use in a cavity resonator to give an efficient pulse compression circuit is described. Switch recovery and turnoff data are given. The effect of superposed dc and RF fields on air breakdown at atmospheric pressures is calculated and used to predict the maximum switching time for different RF-dc field combinations.

3:45–4:15 P.M. Coffee Break

4:15–4:25 P.M.

"Generation of High-Power Nanosecond Pulses of Microwave Energy," M. Gilden and F. A. Jellison, Microwave Associates, Burlington, Mass.

A method of generating high-power nanosecond pulses of microwave energy is described. The technique uses a linear resonator in conjunction with a series gas discharge switch. The peak power values are determined by the use of a low-level reference signal. Pulse lengths as short as two nanoseconds and peak powers of one megawatt were obtained at X-band frequencies.

4:30–4:40 P.M.

"E and H Plane Bends for High-Power Oversized Rectangular Waveguide," J. P. Quine, General Electric Co., Schenectady, N. Y.

Theoretical and experimental results are presented of a study of E and H-plane bends for high-power oversized rectangular waveguide having cross section dimensions in a range between 1.5 and 2.5 free space wavelengths. It is expected that waveguide having these dimensions will be able to transmit 50 to 100 kw of average power at X-band without water cooling. The transmission of at least 5.0 mw of peak power at X-band without pressurization is also a design objective.

A compact H plane constant radius bend is described for which the ratio of center line radius to waveguide width is equal to 1.48. The measured mode conversion loss to the TE_{20}, TE_{30} and TE_{40} modes for an experimental model having a width equal to 2.25 inches was less than −20 db in the frequency range from 7.0 to 11.0 Gc.

The results of computer calculations are also presented for E and H plane bends having variable radii of curvatures. Bends of this type are less compact, but are capable of providing very low mode conversion loss over wide frequency ranges.

4:45–4:55 P.M.

"A High-Power Ferroelectric Limiter," M. Cohn and A. F. Eikenberg, Electronic Communications, Inc., Timonium, Md.

Ferroelectric limiters capable of handling peak input power levels in excess of 25 kw while yielding saturated output power levels of about 300 watts with a small signal insertion loss of 0.5 db have been built. The measured performance and a theoretical analysis have shown that excellent limiting characteristics can be obtained, and that saturation power output levels ranging from a few watts up to megawatts can be obtained with ferroelectric pellets that can be

conveniently fabricated. The limited available material data indicates that ferroelectric limiters will offer their greatest advantage in the HF, VHF and UHF bands. The theoretical analysis of the expected temperature rise within the ferroelectric pellet has shown that by proper design, very high average power levels can also be handled. A recovery time of less than ten microseconds has been measured.

Thursday, May 21, 1964

SESSION V—MICROWAVE SEMICONDUCTORS, PART A

Chairman: R. S. Engelbrecht, Bell Telephone Laboratories, Murray Hill, N. J.

9:00–9:10 A.M.

"Phase Stability of Varactor Frequency Multipliers," R. A. McConnell, Stanford University, Stanford, Calif.

The Stanford two-mile linear accelerator utilizes 30 varactor frequency multipliers in parallel in its radio-frequency drive system. Each multiplier must maintain a phase stability compared to all other multipliers of 1° for a period of one week to insure maximum energy and minimum spectral width of the accelerator electron beam. Phase stability as a function of temperature, bias, drive power and frequency has been measured and the results are presented here.

9:15–9:30 A.M.

"An X-Band Parametric Amplifier with Closed-Cycle Cooling," C. T. Rucker, W. Morrow and E. S. Grimes, Jr., Sperry Microwave Electronics Co., Clearwater, Fla.

A tunable parametric amplifier, operating in the 7.2- to 7.9-Gc frequency range with instantaneous bandwidth of 20 to 30 megacycles is described. The effective noise temperature, including the uncooled four-port circulator, is approximately 70° K when the amplifier structure is cooled to approximately 40° K. The entire parametric amplifier is mounted in an evacuated stainless steel container with provisions for pump and signal connections in the container flange. Cooling is accomplished by connecting the cold finger base of a Norelco "Cryogen" closed-cycle cooler directly to the evacuated container. The freezer (cooling head) is attached to the parametric amplifier by a flexible copper strap. The amplifier can be cooled by other closed-cycle devices or by open-cycle liquid nitrogen techniques if desired. Some interesting features of the amplifier assembly include the use of tellurium copper for the amplifier body, and an unusual method of mounting the amplifier in the evacuated container.

9:35–9:45 A.M.

"The Versatile Tunnel-Diode Video Detector," W. F. Gabriel, Aero Geo Astro Corp., Alexandria, Va.

A C-band, tunnel-diode, video detector has been investigated and is found to be considerably different and more versatile than the older crystal video detector. When biased in the negative resistance region, the detector is simultaneously a detector and an RF amplifier and is characterized by a sensitivity-bandwidth product which is proportional to the gain-bandwidth product of the amplifier. Bandwidth of the detector is easily controlled through bias and RF loading, thus making its sensitivity adjustable. For example, tangential sensitivity can be varied smoothly from −40 dbm to −80 dbm via bias control alone. The detector can deliver either positive or negative video output pulses and, in addition, it functions as a video amplifier stage.

9:50 A.M.–10:00 A.M.

"Solid State V-Band Local Oscillator and Mixer," X. A. De Angelis, Sylvania Electronic Systems, Williamsville, N. Y.

The feasibility of an all-solid-state V-band local oscillator and mixer has been demonstrated. The equipment was developed to overcome millimeter vacuum tube oscillator deficiencies, primarily low operating lifetime and frequency instability. The local oscillator consists of a crystal-controlled transistor oscillator, a transistor multiplier-power amplifier and an eight-stage varactor harmonic generator chain utilizing commercially-available varactors throughout. The resultant 68.5-Gc signal drives a balanced mixer consisting of folder hybrid tee and two wafer diodes in waveguide mounts. Noise figures under 20 db were obtained.

10:05–10:20 A.M.

"Design of Stable Broad-band Tunnel Diode Amplifiers," J. H. Lepoff, Sylvania Electronic Systems, Mountain View, Calif.

An analytic method for designing stable broad-band tunnel diode amplifiers is presented. A double tuned circuit is used to obtain the desired bandwidth. A five-port circulator maintains in-band stability for any mismatch at the input or output ports. A resistive stabilizing circuit reduces out-of-band gain to maintain stability at all frequencies. Four C-band amplifiers were built with more than 10 db gain and less than 5 db noise figure over a 1 Gc band.

10:25–10:55 A.M. Coffee Break

10:55–11:25 A.M.

Invited Paper: "New Device Principles Used in Microwave Diodes," R. M. Ryder, Bell Telephone Laboratories, Murray Hill, N. J.

Modern microwave diodes owe much to transistor techniques, materials and understanding. In contrast to the older point-contact diodes, still universally used in microwave receivers, the new units operate by means of a variety of new principles which were not available until the transistor techniques were applied. This paper describes briefly the new principles and the performance which they make possible.

11:30–11:45 A.M.

"Integrated Circulator Design for Parametric Amplifier Application," C. E. Barnes, Bell Telephone Laboratories, Murray Hill, N. J.

Design considerations and techniques used in the development of a completely integrated, five-circulator package for use in a two-stage, L-band parametric amplifier are presented. Amplifier characteristics were a 19±0.25-db gain in a 20 per cent band and a 1.5-db noise figure in a 15 per cent band. The circulator package characteristics were:

Loss per circulator pass.....	0.15 db
Isolation per isolator.....	30.0 db
Return loss, input and output.....	30.0 db
Return loss, intercirculator..	30.0 db.

The admittance characteristic of the basic circulator was that of a simple parallel resonant circuit shunted by a field dependent conductance. Networks which transform this characteristic into the diverse forms required in the package are discussed. The normalized admittance presented to the amplifier, which critically affects amplifier performance, was controlled to less by better than 0.01 in conductance and ~±0.02 in susceptance.

11:50 A.M.–12:05 P.M.

"Microwave Applications of the Step Recovery Diode," R. B. Mouw and F. S. Coale, Melabs, Palo Alto, Calif.

Silicon P-N junction "step-recovery" diodes have become available within the past two years and have found application as fast switches and higher-order harmonic multipliers. This class of diode is characterized by step-function type discontinuities during reverse recovery. A number of microwave applications for these diodes is described, including narrow-band harmonic generators and generators of broad-band "comb-spectrums" with usable harmonic power up to the 120th harmonic. Design methods and data are given. An interesting property of the thin, diffused P-N junctions used in this application is that certain types have been observed to produce significant microwave power when operated in the reverse breakdown region from an audio generator. An average power of −10 dbm has been measured in a 4-Mc bandwidth centered on 4 Gc. Peak powers are in the order of 10 times average power.

12:10–12:25 P.M.

"A Diode Phase Shifter for Array Antennas," J. F. White, Microwave Associates, Burlington, Mass.

A general canonic circuit form suitable for design of transmission mode, microwave phase shifters employing PIN diodes as control elements is discussed. A convenient-approximate phase-shift formula is derived for the iterative parameter circuit; and analytical treatment of power capability, insertion loss and VSWR is presented. Experimental results are also presented for L and S-band models which have yielded discrete increment phase control at peak power levels up to 15 kw and 140 kw, respectively.

SESSION V—MICROWAVE SEMICONDUCTORS, PART B

Chairman: M. E. Hines, Microwave Associates, Burlington, Mass.

2:30–3:00 P.M.

Invited Paper: "Advances in Solid State Microwave Devices," W. Matthei, U. S. Army Research and Development Laboratories, Fort Monmouth, N. J.

This paper reviews the latest solid state techniques in terms of oscillators, amplifiers, detectors, switches and limiters. Varactors, tunnel diodes, PIN diodes, transistors and other more sophisticated devices, such as those based on hot electrons or phonons, will be discussed in terms of circuit performance and system application.

3:05–3:20 P.M.

"Improvements in Reflex Klystron Linearity with the Use of Varactor Diodes," V. Possenti and A. Pistilli, S.I.T. Siemens Laboratory, Milan, Italy.

Reflex klystron modulation linearity is of paramount importance in radio-link communications. A completely new method of reflex klystron linearization is presented. It is proposed to improve the linearity of the frequency deviation vs reflector voltage characteristic by use of varactor nonlinear capacitance, marking another step toward the growing employment of solid-state devices in microwave radio relay system. The developed theory and the experimental tests (static and dynamic) have shown that it is possible to employ varactor diodes to reduce reflex klystron distortions. Advantages of such a linearization method are described.

3:25–3:40 P.M.

"A 7 Gc Narrow-Band Waveguide Switch Using PIN Junction Diodes," H. J. Peppiatt, A. V. McDaniel, Jr. and J. B. Linker, Jr., General Electric Co., Lynchburg, Va.

The design of a narrow-band waveguide switch using PIN junction diodes in a band-elimination filter is described. The switch will handle switch powers in excess of 8 watts, has more than 80-db rejection for a bandwidth of 10 Mc and a "pass" insertion loss of less than 0.5 db. Measured and theoretical results are presented.

3:45–4:15 P.M. Coffee Break

4:15—4:30 P.M.

"Broad-Band Binary 180° Diode Phase Modulator," R. V. Garver, Harry Diamond Laboratories, Washington, D. C.

Various techniques of phase shifting with diodes are reviewed to determine which is best for making a binary 180° phase modulator. The technique of switching between two transmission lines is selected. The lines are of equal length and the phase shift is obtained by physically twisting the lines with respect to each other before they are rejoined. The resultant 180° phase shift is independent of frequency. Measurements made using this technique at X-band are discussed as well as problems that had to be overcome in using it in a phase-modulated radar system. Further simplifications are indicated which reduce the size and complexity of the device. An equivalent technique in TEM transmission line is given.

4:35–4:45 P.M.

"A Mono-Control Microwave Semiconductor Switch," J. C. Hoover, Sperry Microwave Electronics Co., Clearwater, Fla.

The structure of SPDT microwave semiconductors switches using only reciprocal elements requires the use of at least two independently located diodes. It is desirable, for simplicity of application, that the structure be such that the same switching signal be applied to both diodes to eliminate the need of phase inversion or coordination of two switching signals.

This paper describes a structure called a "Mono-Control" switch that provides an SPDT action with only one control signal. The structure is of particular interest because of its simplicity in that no circulators or hybrids are used. Experimental data is presented of a switch that uses the structure and is designed for the L-band frequency range.

4:50–5:05 P.M.

"Improved Duplexing Techniques Employing Gas TR and Semiconductor Limiter Devices," R. Tenenholtz and P. Basken, Microwave Associates, Burlington, Mass.

During the past twenty years, great strides have been made in the field of gaseous TR devices. However, as in any other technology, optimization of specific characteristics could be secured only with the sacrifice of others. This situation pertains to such characteristics as power handling capability, leakage power, recovery time and life.

Recently, advances in the field of semiconductor limiter technology have opened up a completely new approach to acquisition of the "ideal" TR device. Tests to date performed at X-band and above utilizing gaseous TR tubes and diode limiters have shown that employment of both technologies enables performance never before achieved to be secured.