Report of Advances in Microwave Theory and Techniques in Japan—1959*

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Introduction

THIS report on advances in theory, experiments, and applications of the microwave field is based on papers appearing in the *Journal of the Institute of Electrical Communication Engineers of Japan*, which is the most widespread and well-esteemed journal in the communication and electronics field in Japan. Advances in the realms of microwave sources, detectors, transmission lines, measurements, radiation, and propagation are mentioned.

Sources and Detectors

The traveling-wave-type parametric amplifier consisting of a periodically loaded transmission line with variable capacitance diodes was analyzed theoretically by using a T matrix of each stage which was reduced into a diagonal form [1]. Gain and noise figure characteristics were studied in this analysis. This theory was extended to another one [2], in which a new operator was introduced for the analysis. The operator is a product of a diagonal matrix expressing the pump phase relation and a T matrix of a basic section of a periodically distributed parametric amplifier. Power gain of the amplifier was determined by the use of the characteristic vectors which are derived from the characteristic roots of this operator in the case of the synchronous pumping.[1]

[1] S. Saito, "Transmission line involving parametric elements, especially on periodically distributed parametric amplifier," *J. Inst. Elec. Commun. Engrs. Japan*, vol. 42, pp. 573–579; June, 1959.
[2] K. Kurokawa and J. Hamasaki, "An analysis of periodically distributed parametric amplifier," *ibid.*, vol. 42, pp. 579–585; June, 1959.

The nonlinear barrier capacitance of a silver bonded diode, which is composed of a silver whisker including gallium and an N-type germanium, was studied experimentally. The ratio of the variable capacitance to the constant one of the diode was very large in comparison with that of the usual variable capacitance diode. Cutoff frequency of the diode was as large as more than 400 kmc. The electrical forming was the most important process for the good characteristics of the diode, and the best condition of this process was determined.

[3] S. Kita and K. Sugiyama, "The nonlinear capacitance of silver bonded diode," *ibid.*, vol. 42, pp. 1186–1192; December, 1959.

The available output power of a ferrite parametric oscillator was discussed theoretically. In an ideal case in which RF fields of the signal and idler are uniform in a spherical ferrite sample, a magnitude of a uniform precession increases as the pump power becomes large. However, the magnitude cannot exceed a certain value after the generation of oscillation, even though the pump power increases. Power loss in the sample, except that due to the excitation of the uniform precession, may be neglected. If the RF fields in the sample are not uniform, further loss due to the nonuniformity increases with the pump power. Therefore, actual available power is limited by the loss in the sample.

[4] T. Hashimoto, "Theoretical consideration on the output power of Mavar," *ibid.*, vol. 42, pp. 1193–1199; December, 1959.

A disk-on-rod circuit, which is composed of a disk-loaded inner conductor and an outer shield, was studied as a slow wave circuit of a traveling-wave tube. The coupling between a higher order mode of the circuit and an electron beam, which flowed axially, was analyzed. Formulas for the phase constants and coupling impedances of the lowest and higher modes were derived. For the convenience of designing the circuit, cutoff frequencies, phase constants, and coupling impedances for the specified frequencies were given in figures. The measured values of the guided wavelength were in good agreement with the theoretical ones.

[5] K. Ura, M. Terada, and E. Sugata, "Analysis of higher mode operation of disk-on-rod type traveling wave tubes," *ibid.*, vol. 42, pp. 145–150; February, 1959.

A traveling-wave tube with a cavity as an input buncher was proposed for an efficient frequency multiplier. The effect of a drift space between input buncher cavity and output helix of the traveling-wave tube on the harmonic generation was studied theoretically, and the efficiency could be remarkably increased by choosing the length of the drift space properly. The experimental results on the determination of the optimum length of the drift space agreed substantially with the theoretical ones. The fifth harmonic power of −25 db below the input power of 4160 mc was obtained experimentally.

[6] K. Morita and M. Kawamura, "Effect of drift space on the harmonic power by cavity type traveling wave tube," *ibid.*, vol. 42, pp. 159–164; February, 1959.

The space charge effect in a reflex klystron was studied analytically by the successive approximation

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[1] The contents of this paper were also published in K. Kurokawa and J. Hamasaki, "Mode theory of lossless periodically distributed parametric amplifiers," IRE Trans. on Microwave Theory and Techniques, vol. MTT-7, pp. 360–365; July, 1959.

method. Formulas of correction factors due to space charge for a bunching angle and a phase angle were derived. In case of rather large transit cycle, the bunching efficiency was expressed approximately in the form of a simple equation. The results were proved to be applicable to the usual reflex klystron, and also may be useful in evaluating the space charge effect of the reflex klystron.

[7] M. Terada, H. Hamada, and E. Sugata, "Space charge effects in reflex klystron," *ibid.*, vol. 42, pp. 591–597; June, 1959.

A transfer function of an *O*-type backward-wave oscillator was obtained assuming that the tube acts as a linear device and that steady-state frequency response may be expressed approximately by power series expansion of a pair of poles [8]. Build-up time of the oscillator output and frequency pushing characteristics may be derived from this function. The output signal for the pulsed backward-wave amplifier may be calculated through the use of the Laplace transformation. Furthermore, the frequency pushing characteristics of an *O*-type backward-wave oscillator were analyzed in detail, taking the effects of space charge and circuit loss into account [9]. The results were confirmed experimentally by a helix-type backward-wave oscillator, and were in good agreement with measured values.

[8] I. Sakuraba, "Transfer function of the *O*-type backward-wave oscillator," *ibid.*, vol. 42, pp. 750–754; August, 1959.
[9] I. Sakuraba, "Anlaysis of the *O*-type backward-wave oscillator frequency pushing," *ibid.*, vol. 42, pp. 810–815; September, 1959.

Reduction of the beam noise was studied with respect to the power theorem. It is impossible to remove the beam noise in the slow wave, but the beam noise in the fast wave may be reduced because of the fact that the slow wave carries the negative power, whereas the fast wave has the positive one. Cavity coupler and helix coupler for a fast wave amplifier such as a parametric amplifier were proposed for the removal of the beam noise. The optimum noise figures were given theoretically in both cases.

[10] S. Saito, "Some consideration of beam noise reduction from the point of power theorem, especially on fast wave amplifier," *ibid.*, vol. 42, pp. 221–225; March, 1959.

A novel theory on the minimum noise figure of a traveling-wave tube was derived. This is based on the Haus-Robinson theory concerning the minimum noise figure and the earlier theory on the noise reduction at the potential minimum plane proposed by Watkins. Higher current density at the potential minimum plane is more desirable and extreme low-noise figure, for example 2.2 db for 1000 mc, may be obtained, if current density as high as 300 ma/cm^2 at the potential minimum plane could be realized near the temperature-limited region. A divergent electron gun with a very small cathode area should be used for a low-noise traveling-wave tube, because large beam current is undesirable for that type of tube.

[11] T. Ohkoshi, "On the minimum noise figure of traveling wave tubes—a theory considering the noise of the potential minimum plane," *ibid.*, vol. 42, pp. 833–838; September, 1959.

Transmission Lines

Advanced surface waveguides composed of thin dielectric sheets were proposed as a low-loss transmission line. The electric field is parallel to the dielectric sheet in the field configuration of the propagation mode. Two examples of *O* guide, which consists of a hollow cylindrical thin dielectric, and *X* guide, having an *X*-shaped dielectric structure in cross section, were described. The TE fundamental mode for the *O* guide was analyzed and its theoretical characteristics as a transmission line were discussed. A practical guide, such as thin polyethylene tube, is suitable for the SHF region, where the attenuation constant is lower than that of the coaxial line, *G*-line, and rectangular waveguide.[2]

[12] M. Sugi and T. Nakahara, "Surface wave transmission line composed of dielectric sheet," *ibid.*, vol. 42, pp. 731–737; August, 1959.

A new variational principle was proved for the determination of the propagation constant of waveguide with wall impedance. The effect of the small wall impedance on the propagation constant and the separation of a degeneracy was discussed in detail. These results were compared with that from the perturbation method, which was improved to be applicable to a waveguide with inhomogeneous media. In this analysis, not only the TE and TM modes but also the TEM and hybrid modes may be treated simultaneously.

[13] K. Kurokawa, "Propagation constants of waveguides with wall impedances," *ibid.*, vol. 42, pp. 60–61; January, 1959.

In a taper-type circular electric mode transducer, unwanted modes were analyzed in the excitation of the TE_{01} mode. Telegraphist's equations of the transducer were derived in an oblique coordinate of a helix system by introducing the expanded transverse fields in terms of normal mode functions of sector waveguides into Maxwell's equations. From these telegraphist's equations inhomogeneous second-order linear differential equations were obtained. Magnitudes of the unwanted modes were determined by integrating these equations numerically. The theoretical values of the unwanted TE_{11}, TE_{21}, TE_{31}, and TM_{11} modes were in good agreement with measured values.

[14] S. Iiguchi, "Mode conversion in excitation of TE_{01} wave through TE_{01} mode transducer," *ibid.*, vol. 42, pp. 1213–1219; December, 1959.

An adjustable phase shifter for the circular electric mode was proposed. A movable dielectric rod is located coaxially inside a concentric dielectric layer in a circular waveguide. There is an optimum ratio between the radii of the rod and the circular waveguide.

[15] S. Kumagai and N. Kumagai, "An adjustable phase shifter for circular electric mode," *ibid.*, vol. 42, p. 61; January, 1959.

[2] The contents of this paper also appeared in M. Sugi and T. Nakahara, "*O*-guide and *X*-guide: an advanced surface wave transmission concept," IRE Trans. on Microwave Theory and Techniques, vol. MTT-7, pp. 366–369; July, 1959.

Measurements

Tensor permeability and dielectric constant of ferrite were measured by the use of a rectangular cavity of the TE_{101} or TM_{120} degenerate mode at 7 kmc. In this method all components of the permeability and dielectric constant can be measured by changing the position of a thin disk ferrite sample in the cavity. Errors due to slight unsymmetry of the sample or cavity were evaluated by the perturbation method. The measured values were compared with that from the resonant theory.

[16] F. Okada, "Measurement of ferrite constants by rectangular cavity resonators," *ibid.*, vol. 42, pp. 758–764; August, 1959.

Microwave measurements employing spark waves as a microwave source were proposed. Because of the wide-band frequency spectrum characteristics of the spark waves, circuit constant cannot be measured directly. In a case of VSWR measurement, a measured value may be transformed into a real value by known frequency characterisitcs of band-pass filter connected at the output of the source.

[17] T. Kawano, "Measurements of microwave circuit elements employing spark waves," *ibid.*, vol. 42, pp. 62–63; January, 1959.

Radiation and Propagation

Radiators of an Echelette grating spectrometer for millimeter waves were studied in order to obtain a general understanding about the operating principle using an analogy for an optical instrument. To avoid the near-zone effect, electromagnetic horns with small apertures were employed. It was shown both theoretically and experimentally that an inevitable phase error due to spherical phase fronts of horns was allowable up to about 120°. Although a large parabolic mirror has a complicated radiation pattern in the near-zone region, the phase front deviation from a plane wave is no more than a few tens of degrees. Therefore, the performance of the spectrometer is satisfactory even for a short distance between the antenna and the grating.

[18] T. Sueta, "A study on antenna for millimeter wave grating spectrometer," *ibid.*, vol. 42, pp. 677–683; July, 1959.

To transmit microwaves over a mountain, two large flat conducting plates located close to each other are often used as reflectors for a passive repeater, which is called the passive repeater of the second kind. Since this system may be considered as a special application of a microwave periscope, the propagation loss may be calculated through an analysis of a receiving antenna in the Fresnel zone. The results were compared with that determined through the scattered field by the Huygens principle, and they agreed with each other.

[19] T. Soejima, "Passive repeater of the second kind using double flat reflectors," *ibid.*, vol. 42, pp. 502–507; May, 1959.

In a case where the plane wave was incident to a thin dielectric spherical shell, an internal electromagnetic field was calculated approximately from Maxwell's equations by a direct integral method. From this analysis a simple formula for a back-scattering cross section was derived which may be applicable for the whole range of $ka(k=2\pi/\lambda$, and a is a radius of the shell) and the refraction coefficient of the shell.

[20] A. Yokoyama, "Back-scattering of a thin dielectric spherical shell," *ibid.*, vol. 42, pp. 36–39; February, 1959.

Effective reflection coefficients of snow surfaces were measured over a snow-covered terrain of 100 meters distance in the X band, and were compared with that of the 4-kmc band. Dependence of the effective reflection coefficient on the complex dielectric constant of snow was studied, and a new parameter, derived from Fresnel's reflection equation, was introduced. The dielectric properties of snow had a fairly large influence on the variation of the effective reflection coefficients, which was considerably greater than that given in the 4-kmc band. If the snow surface was rough, larger scattering of the incident wave was obtained at 9 kmc than at 4 kmc.

[21] M. Suzuki, "Equivalent reflection coefficient in 9-kmc band propagation over snow covered terrain," *ibid.*, vol. 42, pp. 490–405; May, 1959.

Microwave fading and fluctuation of communication quality in microwave relay links were studied statistically in order to find a communication transmission standard. Many fundamental propagation tests and measurements of fading and thermal noise at actual microwave links were carried out. Analysis was made from numerous measured values, and important factors for the design of the microwave radio links were clarified.

[22] K. Morita, "Fading of microwave relay links," *ibid.*, vol. 42, pp. 923–929; October, 1959.

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