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Microwaves at Japanese Universities

Introduction

The present status of the research in the fields of microwaves, millimeter waves, and coherent optical waves at Japanese universities is reviewed. A representative bibliography of over 90 references, which have appeared during the period of the last two years, including the papers to be published shortly, appears at the end of this summary. Among these, some selected topics are described herein briefly. Excluded are most of the works in microwave antennas and propagations, microwave tubes, and the physics of quantum electronics.

Like the recent trends in the United States and Europe, the current interest of the microwave researchers at Japanese universities is changing from the conventional microwave or millimeter wave transmission lines and components to the newly developed subjects such as leaky waveguides and beam waveguides, plasma electronics, quantum electronics, coherent electromagnetic optics, and related areas. This would be seen from the references listed which are divided into eleven subject categories.

I. Electromagnetic Wave Theory [1]–[10]

The leaky wave modes, and the surface waves in magnetoionic medium are studied mathematically. In connection with the future space communications technology, some basic problems, for instance, the electromagnetic radiation which would be produced by the oscillating electric dipole moving in free space with constant relativistic velocity, are analyzed [10]. It is shown that the energy density radiated from the moving dipole increases with velocity in the direction of motion and, conversely, it decreases in the opposite direction.

II. Waveguide Theory [11]–[17]

The waveguides containing inhomogeneous dielectrics [14], the slab of arbitrary admittance [13], and the waveguide filled with media composed of dielectrics and metallic blades [17] are treated. The expressions for the equivalent width of the waveguide composed of arbitrary wall impedances are derived [12], which may conveniently be used for the analysis of nonconventional waveguides such as striplines or trough waveguides.

A new family of "parabolic waveguide" whose cross section is formed by a pair of symmetric confocal parabolic conducting walls is proposed, and the interesting and promising features are shown theoretically [16].

III. Circular TE_{01} Waveguide [18]–[25]

The reflection and the mode conversion in multimode waveguide are discussed with emphasis on the resonance phenomena which would occur at, or in the immediate vicinity of, the cutoff frequencies of the modes involved [23]–[25].

An interesting novel method to prevent the mode conversion losses at a circular bend of the TE_{01} waveguide using inhomogeneous dielectrics and anisotropic wall impedance is proposed [20]. It is shown that the undesired coupling between the signal TE_{01} mode and both the unwanted TM_{11} and TE_{1n} modes due to the circular bend can be cancelled out all along the bend. This is accomplished by introducing a coupling of equal magnitude and opposite sign to that produced by the bend, by making an appropriate distribution of the permittivity across the cross section of the curved guide and an appropriate circumferential variation of the surface impedance of the guide wall. It is shown also that the appropriate slight deformation of the circular cross section of the curved guide provides just the same effect as that of an anisotropic wall impedance [19].

IV. Microwave Filters [26]–[29]

A design theory for the narrow band-pass harmonic resonator filters having extremely high midband frequency is developed, and is successfully confirmed by experiments at x-band [27]. A practical millimeter wave branching filter [29], three-path TEM-line higher harmonic rejection filter [26], and a utilization of the superconductivity for the low loss microwave filter [28] are studied.

V. Plasma Waveguides and Ferrite-Loaded Waveguides [30]–[35]

The electromagnetic fields in the ferrite-loaded cavities [30], [31] are analyzed theoretically in detail. The characteristics of the plasma-filled waveguides [33]–[35] and a parametric oscillation and amplification using YIG disk [32] are discussed.

VI. Open-Type Waveguides and Leaky Waveguides [36]–[46]

The beam waveguides, leaky waveguides, and surface waveguides, are being studied both from the theoretical interest and the interest of practical applications, especially to the high-speed-train control, train communications, and detection of obstacles on the railway track. The reflecting beam waveguides consisting of curved-strip conducting reflectors [36], and of cylindrical conducting reflectors [37] are analyzed theoretically.

VII. Microwave Measurements [47]–[52]

Synthesis of broadband matched load or absorbing wall is developed [48], [49]. A high sensitivity millimeter wave detection system is proposed [51]. The improved technique for measuring dielectric constants, [52] and the technique for precise measurement of the field distribution of surface waves [47] are also proposed.

VIII. Quasi-Optics and Optical Waveguides [53]–[60]

The wide-band quasi-optic dielectric prism components such as directional couplers, attenuators, and magic-tees using the Brewster angle matching technique are proposed [53], and are operated successfully at both millimeter [53] and optical [88] wavelengths. Because of the Brewster angle matching, the wave suffers no spurious reflections at the input and output boundary surfaces between air and dielectric, over a very large range of the frequencies affected only by the dispersion of the prism materials. Thus, directivity, broadbandness,

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and other performance characteristics are improved remarkably as compared with the conventional prism components reported so far.

A light beam waveguide consists of lens-like media having hyperbolic temperature distribution across the transverse plane is proposed [55], [56]. The hyperbolic temperature distribution provides the pure quadratic variation of the dielectric constant, thereby enabling the mode conversion losses to be minimized.

IX. Optical Resonators [61]–[69]

The resonant modes in a Fabry–Perot resonator consisting of nonuniform reflectors, i.e., the reflectors whose reflectivities are the function of position across the reflecting surfaces, are analyzed theoretically, and their application to the laser resonator is discussed [65].

The cylindrical Fabry-Perot resonators are also treated, and a novel construction of a high power, single frequency laser is proposed [64]. A cavity theory for the Fabry–Perot resonators is developed [66]–[68].

X. Lasers—Circuit-Theoretic Treatments and Design Considerations [70]–[79]

The use of well-developed circuit theory techniques in designing the optical devices and systems is currently one of the subjects of engineering interest [70]–[77]. Research is being done not only on the development of engineering design techniques for the optical devices, but also it is being done to develop a method of analyzing the quantum actions themselves on the basis of the electric circuit theory point of view [74]. By introducing the appropriate correspondences between the quantities appearing in the conventional energy-level-models and in the equivalent electric-circuit models, the quantum mechanical energy-level-model analysis based on the rate equations can be transformed into the electric-circuit-model analysis based on the circuit equations, which is much more familiar to most of the electrical engineers. The information transmission in quantum circuits is also being studied [76].

XI. Coherent Light Technology [80]–[92]

Studies on the coherent-light technologies such as light-modulation techniques, optical devices, and systems design, including a laser radar application in atmospheric physics research, etc., are being carried on.

Conclusions

In summary, the conventional microwave and millimter-wave research at Japanese universities seem to have had their day, and the day of research and developments of nonconventional guided waves such as leaky waves and beam waves, and closely related topics on microwaves through optical frequencies is here. Intense activity is occurring in analysis, synthesis, and design of laser devices and optical components to cover a wide range of applications.

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Optimal Design of Matching Networks for Microwave Transistor Amplifiers

***Abstract*—The design of input and output matching networks for transistor microwave frequency amplifiers has been optimized by the use of an efficient computer program. Power amplifiers capable of 2.5 watt peak power output with a 400 MHz bandwidth at 2.25 GHz have been fabricated. The matching network problem was reduced to an equivalent nonlinear programming problem by considering the *N*-filter elements as coordinates in a 2*N*-dimensional vector space. The optimal solution point in the vector space was found by the use of a "pattern search" routine which utilized randomly chosen orthogonal transformations of the search pattern to minimize an objective function. In this case, a suitable objective function was chosen to be the area under the curve of "reflection coefficient" vs. frequency for the filter input. By use of multiple data input as many as six designs have been achieved in less than nine minutes on the 7044 computer.**

Introduction

Construction of transistor amplifiers at microwave frequencies involves the design of suitable matching networks as shown in Fig. 1. Power amplifiers are further complicated by nonlinear operation to give efficiency as well as gain. The natural step to integrated microwave transistor amplifiers imposes a minimal size constraint upon the matching network design. Additional constraints such as transistor biasing networks and coupling capacitor dimensions must also be considered. The characterization techniques used to obtain the transistor input and output admittances have been previously described [1]. The admittances generally cannot be ascribed to a simple equivalent circuit. The technique described in this paper allows networks, consisting of lossless transmission lines, to be designed to match the measured admittances over a broad range of frequencies. An extension of the technique to lumped parameter elements also has been made.

We have characterized either port of a transistor as an admittance for the purposes of this discussion. This admittance is generally a function of both power level and frequency as shown in Fig. 2. Upon choosing an operating level, the admittance is given in terms of frequency alone. By least squares curve fitting, an admittance vs. frequency function may be empirically described. In general, two such admittance functions are given to be matched to one another by the use of a suitable network. The case described below utilizes lossless transmission line elements and capacitors to construct an admittance matching network over a broad band of frequencies.

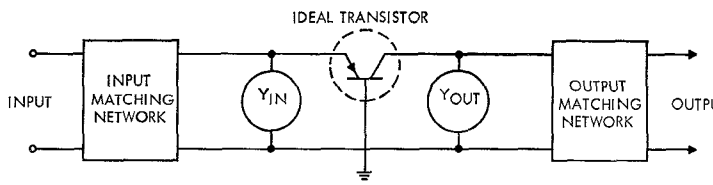

Fig. 1. Schematic diagram of a single stage transistor microwave amplifier. The output may be the input admittance of the next transistor stage.

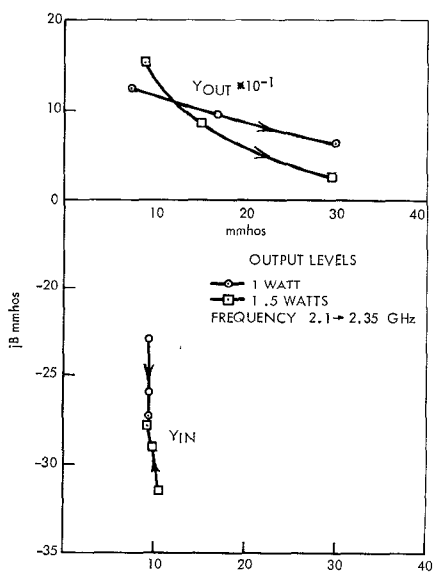

Fig. 2. Typical transistor admittance functions.

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