# Theoretical Consideration on Parallel–Plate Waveguide Modes of a Slot Antenna with a Reflector

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## 1.INTRODUCTION

A slot antenna which has a reflector is widely used as an element of antenna arrays. However, parallel–plate waveguide modes[1] are excited by the slot and propagate between a conductor on which the slot is cut and the reflector.The parallel–plate waveguide modes affect the radiation characteristics of the slot, such as the degradation of the radiation efficiency. An aim of this paper is to make a mechanism of the excitation of the parallel–plate waveguide modes clear theoretically. Moreover, this paper presents and discusses numerical results.

## 2.FORMULATION

The configuration of the structure is given in Fig.1, where a rectangular narrow slot of length $l_s$ and width $w_s$ is cut on a ground plane(#1). A dielectric of relative permittivity $\varepsilon_{1r}$ is filled between two conducting ground plane, that is, plane(#1) and a reflector(#2) which are separated in a space $d$. The ground planes are assumed to be infinite. The slot is fed by an ideal delta-gap current source at the center of the slot. When the separation $d$ is infinite, the slot with the reflector becomes a slot without reflector which is shown in Fig.2. This paper analyzes two models shown in Figs.1 and 2. The boundary conditions ($\overline{H}^{tan}$ is continuous through the slot) are enforced in the spectral domain, where the unknown is the magnetic current density in the slot. Using Galerkin's method in the spectral domain, magnetic field equation reduces to the following matrix equation to be solved for the unknown amplitude, that is, $\overline{V}_+$, of the slot:

$$[\overline{\overline{Y}}_+ + \overline{\overline{Y}}_-][\overline{V}_+] = [\overline{I}^i] \tag{1}$$

where $\overline{\overline{Y}}_+$ and $\overline{\overline{Y}}_-$ are generalized admittance matrices (estimated for region + and region −, respectively), $\overline{I}^i$ is generalized incident current vector, and $\overline{V}_+$ is unknown amplitude vector of expansion modes for slot. Solving the matrix equation (1) for unknown amplitude vector $\overline{V}_+$, it clarifies the magnetic current density, and using this result, the various characteristics of the model structure can be estimated (see [2] in detail).

## 3.NUMERICAL RESULT

First, Fig.3 shows the input impedance of the slot shown in Fig.2 where $\varepsilon_{1r} = 1$. In this case, a half of power is radiated to the upper half space. Therefore, radiation efficiency which is estimated in the upper half space is 50%. Next, we discuss the slot of Fig.1. In this case, there exist various propagating modes between two ground planes which are varied with the separation $d$ as shown in Fig.4. Thus, radiation efficiency as well as input impedance is varied drastically with the separation $d$. The input impedance versus the separation $d$ are shown in Fig.5, where $d$ is normalized by the wavelength of TEM mode in the parallel-plate waveguide. Fig.5 shows that the input impedance oscillates and approaches to that of the slot without the reflector shown in Fig.3, as $d$ increases. When $d$ equals $0.5\lambda$ or $\lambda$, the reflector works as the short plane as shown in Fig.5. Higher modes such as TM and TE as well as TEM mode can propagate when the separation $d$ becomes more than $0.5\lambda$. Therefore, there exists sharp change at $d$ of $0.5\lambda$. Figs.6 and 7 show the power and efficiency versus the separation $d$. These figures also show same behavior as shown in Fig.5.

## 4.CONCLUSION

Using Galerkin's method in spectral-domain, the authors clarify that parallel-plate waveguide modes, which are excited by the slot antenna with the reflector,have a harmful influence on the antenna characteristics. The generation of higher harmonic parallel-plate waveguide modes changes the radiation efficiency and input impedance drastically, for example. This paper furnishes with basic design data for a printed slot array antenna.


## Acknowledgement

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## REFERENCE


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[2] T.Nakamura and K. Itoh :"An Antenna System with Coupling between Electric and Magnetic Current Sources in a Multilayered Medium," ISAP89, 2A4-1.

[3] D.M.Pozar, et al. :"Comparison of Architectures for Monolithic Phased Array Antennas," Microwave Journal, vol.29, pp.93-104, March 1986.


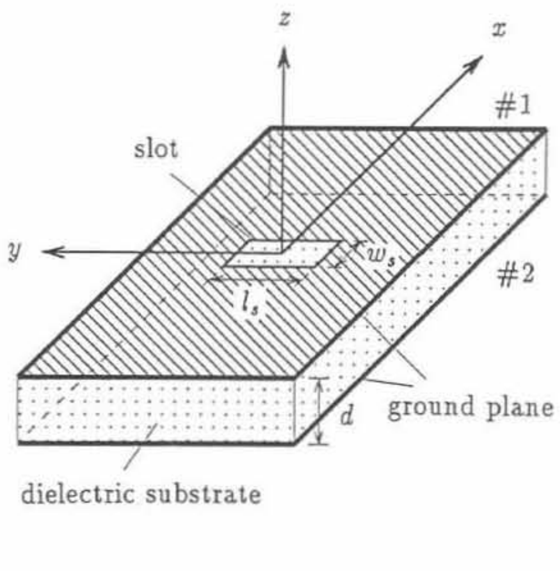


Fig.1: Configuration of a slot with a reflector.

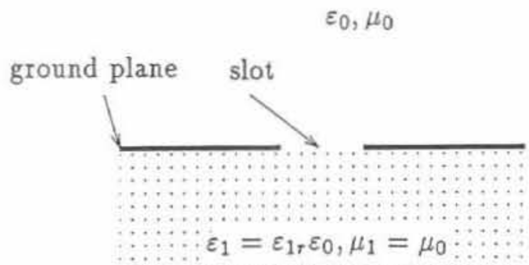


Fig.2: A slot without reflector.

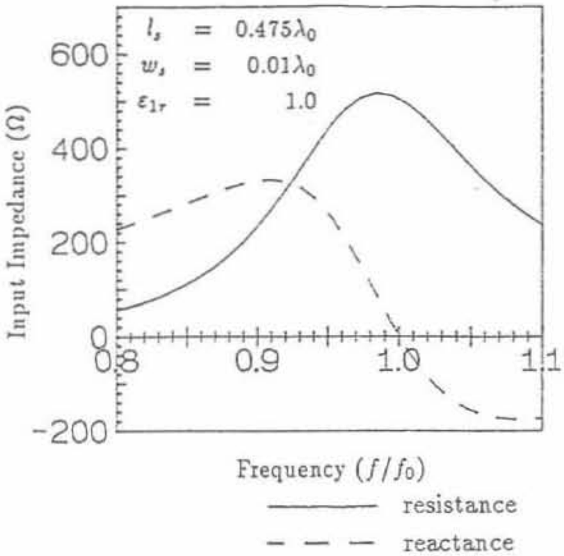


Fig.3: Input impedance of a slot without reflector versus frequency normalized by resonant frequency, $f_0$.

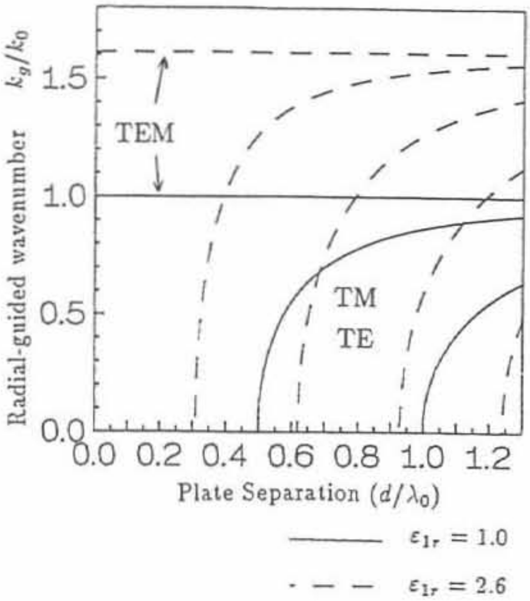


Fig.4: Propagation modes supported by a parallel–plate waveguide structure versus plate separation (normalized by $\lambda_0$).

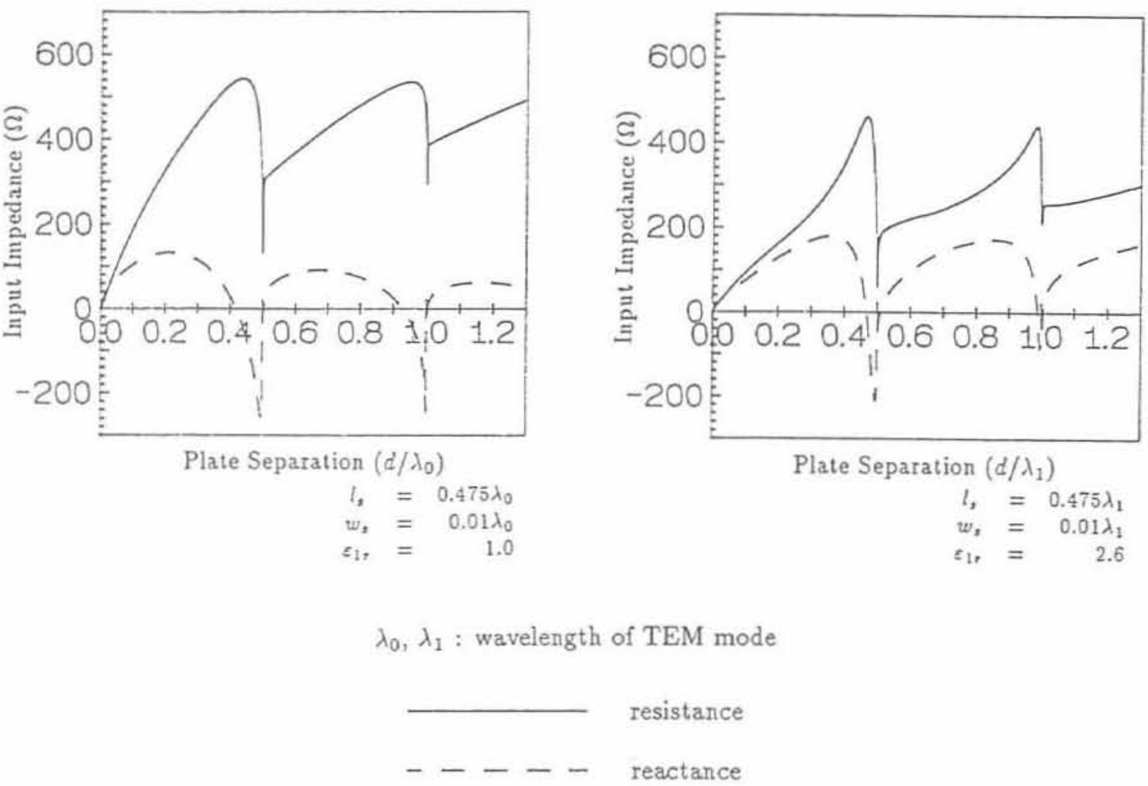


Fig.5: Input impedance of a slot with a reflector versus plate separation (normalized by a wavelength of TEM mode).

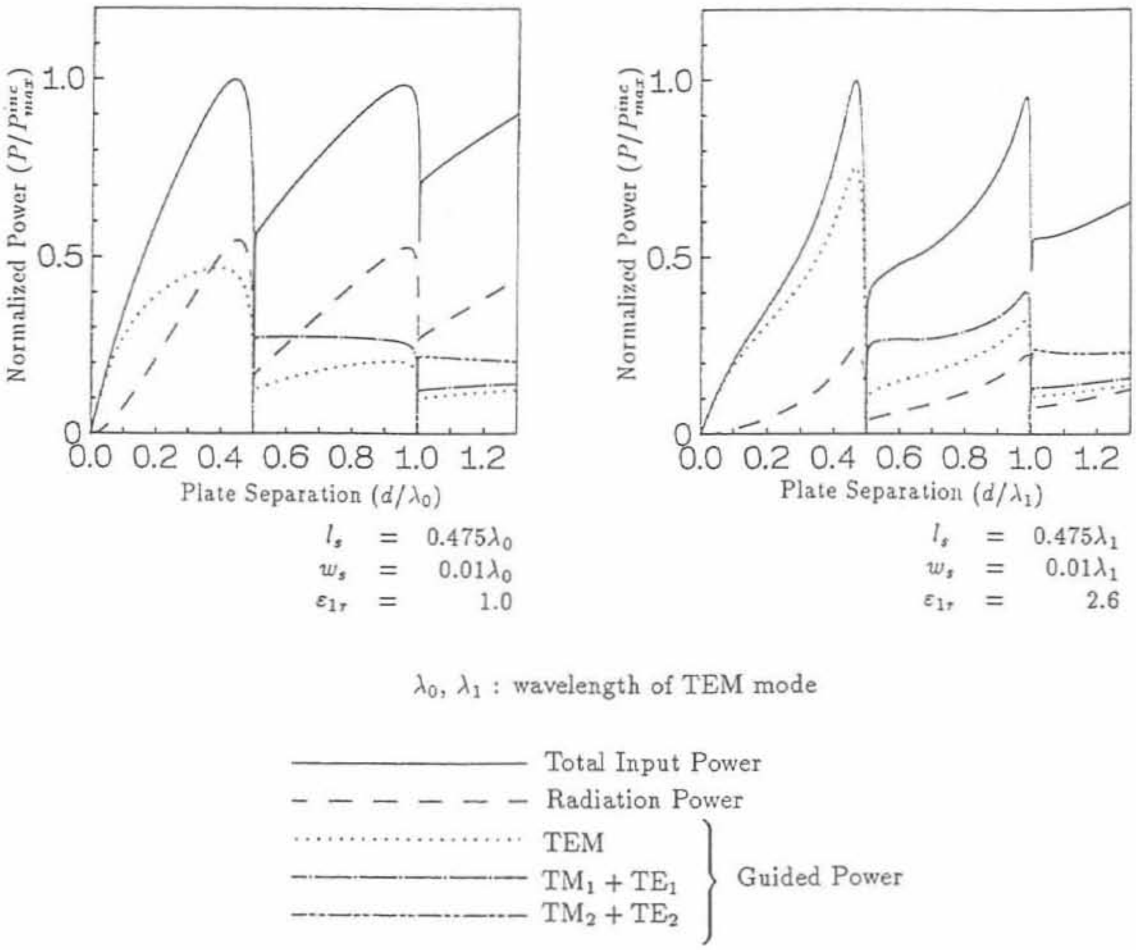


Fig.6: Power of a slot with a reflector (normalized by the maximum input power) versus plate separation (normalized by a wavelength of TEM mode).

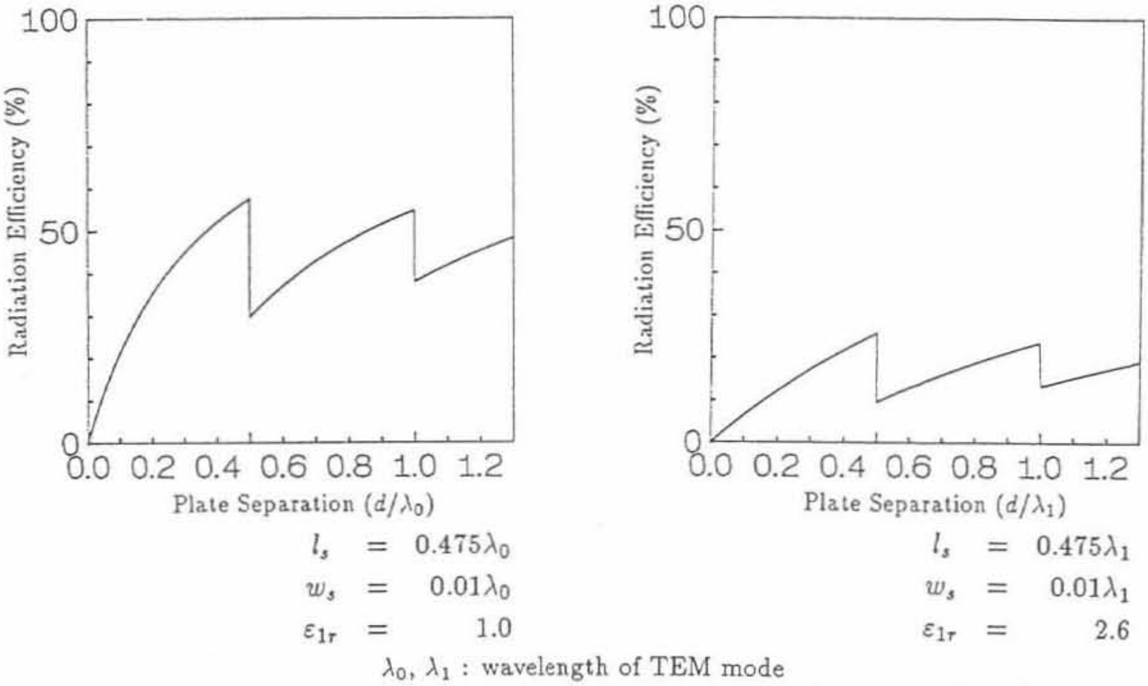


Fig.7: Radiation efficiency of a slot with a reflector versus plate separation (normalized by a wavelength of TEM mode).