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# STUB-LOADED RIDGE WAVEGUIDE OF SINGLE-MODE OPERATION FOR USE OF LEAKY-WAVE ANTENNAS

Mikio TSUJI, Masaki TANI, Hiroyuki DEGUCHI, and Hiroshi SHIGESAWA
Department of Electronics, Doshisha University
Kyotanabe, Kyoto 610-0321, Japan
E-mail mtsuji@mail.doshisha.ac.jp

## 1. Introduction

Leaky-wave antennas based on an open-waveguide structure can become a candidate of millimeter-wave antennas because an open structure can easily produce a radiation along its length due to a leaky mode by introducing not a partly physical cut, but asymmetry of the structure. One of these open waveguides for antenna purposes is the stub-loaded ridge-rectangular waveguide shown in Fig. 1, which consists of a ridge-rectangular waveguide with an asymmetrically located stub guide[1][2]. This guide radiates in a single polarization (with negligible cross polarization at all scan angles), possesses flexibility in beamwidth, and scans the angle of maximum radiation by changing the frequency. Its guide width can be reduced to less than a half wavelength by the ridging effect, so that for use of a scanning array antenna, extra main beam due to a grating lobe can be avoided. Furthermore, since it has many structural parameters, we have developed the antenna with the Taylor distribution of –30dB sidelobes by adjusting the parameters well[3][4]. However, this guide structure developed by us has an inherent drawback that the channel-guide leaky mode[5] propagates simultaneously together with the desired leaky mode and affects the radiation field. For antenna applications, the guide should be used in a single-mode operation in which only the desired leaky mode propagates and the channel guide one is below cutoff. Therefore in this paper, we propose a new structure of the stub-loaded ridge waveguide that realizes the single-mode operation. The proposed structure includes many conductor edges at which the fields diverge, so its leakage characteristics are accurately calculated by the mode-matching method incorporating the singular field behavior into the aperture-field expressions[2][6]. As a result, we find out the guide with the single–mode operation and its verification are performed from the FDTD calculation and also the measurements for the fabricated guide.

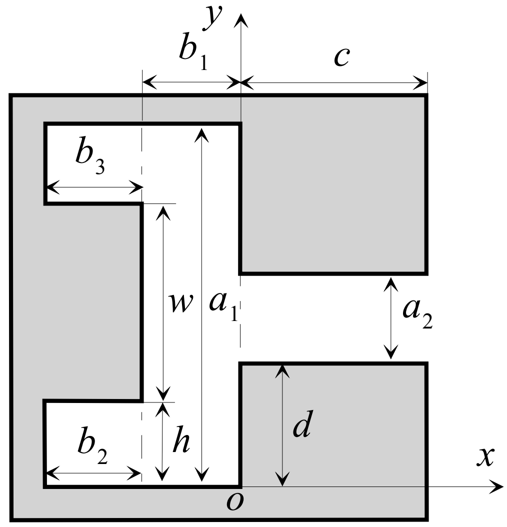


Fig. 1. Cross-section view of a conventional stub-loaded ridge-rectangular waveguide.

## 2. Propagation Characteristics of the Conventional Structure

Figure 2 shows a typical example of the dispersion characteristic for the conventional stub-loaded ridge-rectangular waveguide shown in Fig. 1. The guide dimensions are indicated in the inset of the figure. It is found from this figure that the desired leaky mode and the channel-guide one propagate simultaneously in certain frequency range. The desired leaky mode is mainly polarized in the $x$ direction and the stub-guide portion works perturbationally, while the channel-guide one is mainly polarized in the $y$ direction and the whole structure works as a guide. Figure 3 shows the surface current distribution on the $yz$ conductor plane at $x$=$c$ for various frequencies. These results are calculated by the FDTD method. The current distribution clearly beats in some period due to interaction between two leaky modes. The beat wavelength obtained from the current distribution agrees with that calculated by the difference between the phase constants

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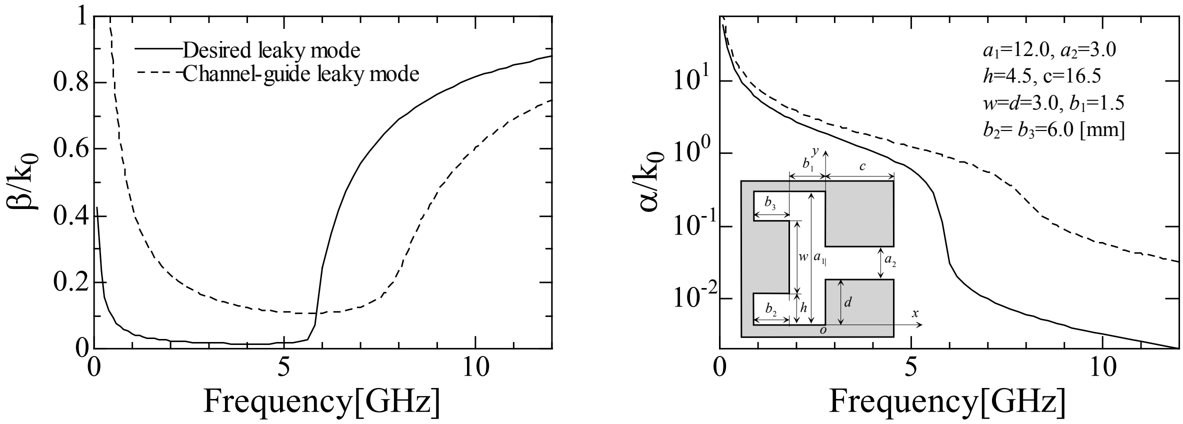


Fig. 2. Normalized phase and leakage constants of the desired and the channel-guide leaky modes for the conventional guide as a function of the frequency.

of both modes shown in Fig. 2. If the length $c$ of the stub guide is very short, the cutoff frequency of the channel guide becomes higher and the single-mode operation may be realized. But in this case, the higher-order mode of the stub guide except for the parallel-plate mode has influence on the aperture of the stub guide, so that the merit of a linear-polarized radiation is lost. Therefore in the next section, we propose a new structure for the single-mode operation, keeping the stub guide certain length.

## 3. New Structure for Single-mode Operation

Figure 4 shows a proposed new structure for the single-mode operation. This guide has a ridge on a side opposite to the conventional guide shown in Fig.1 and the stub guide is installed in the ridge. By taking this structure, the distance between the aperture of the stub guide at $x=c$ and the metal wall at $x=-b_1$ becomes short so that the cutoff frequency of only the channel-guide mode can be make higher. Figures 5 shows a typical example of the normalized phase constant $\beta/k_0$ and the leakage constant $\alpha/k_0$ for the desired and the channel-guide leaky modes. We can observe that the

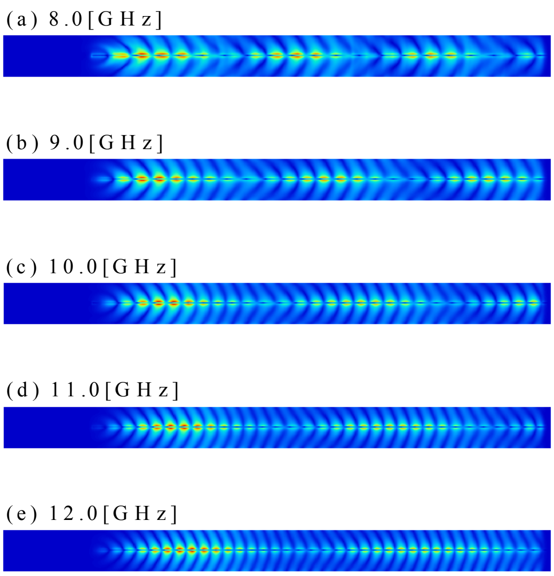


Fig. 3. Surface-current distribution on the $yz$ conductor plane at $x=c$ for the conventional guide.

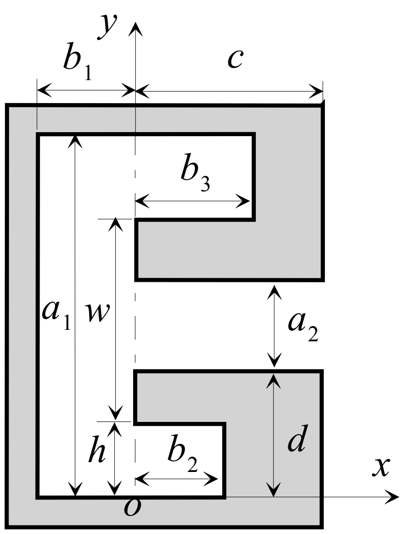

Fig. 4. Cross-section view of a proposed stub-loaded ridge-rectangular waveguide for single–mode operation.

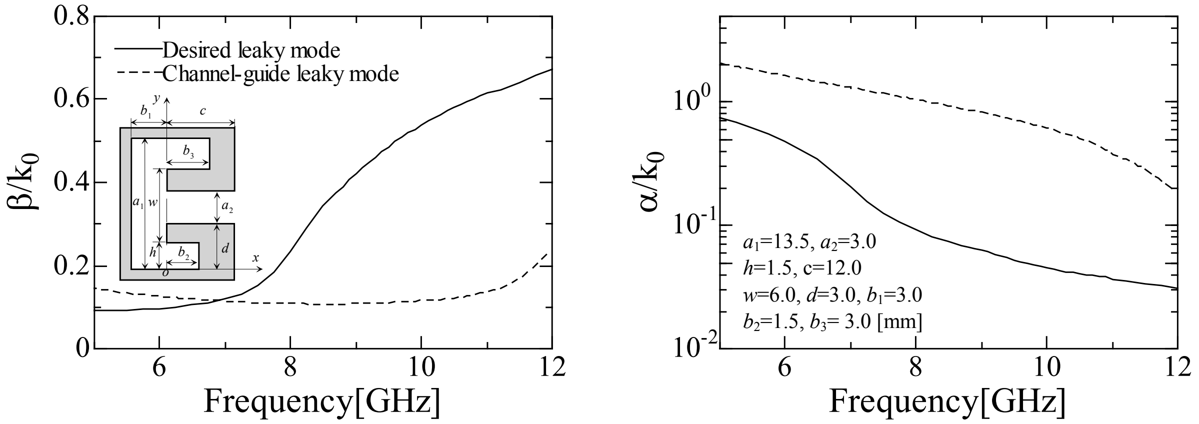


Fig. 5. Normalized phase and leakage constants of the desired and the channel-guide leaky modes for the proposed guide as a function of the frequency.

single-mode operation is obtained from 8GHz to 11.5GHz. It should be noted here that the normalized phase constant $\beta/k_0$ does not become zero below cutoff because of leakage. To verify the single-mode operation, Figure 6 shows the surface current distribution on the *yz* conductor plane at $x=c$ for various frequencies, which are calculated by the FDTD method. In this case, the current distributions clearly do not beat except for 12GHz, different form those in Fig. 2, so that the guide supports only the desired leaky mode. Therefore this guide structure is very effective for antenna applications. The detailed dependence of the structural parameters on the dispersion behavior will be presented at the talk.

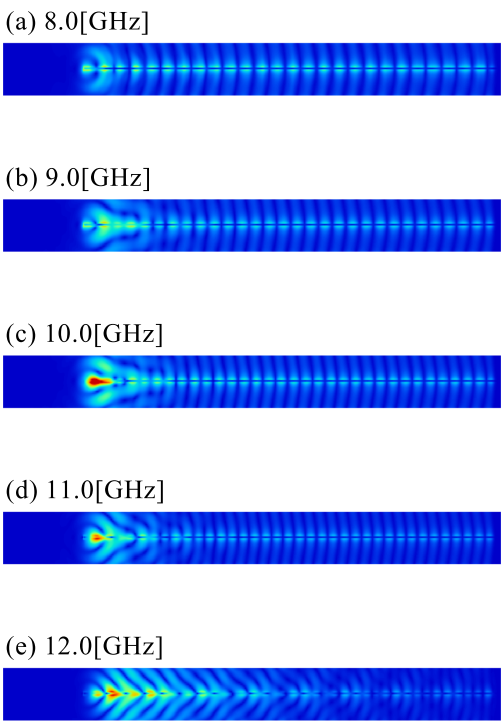


Fig. 6. Surface-current distribution on the *yz* conductor plane at $x=c$ for the conventional guide.

## 4. Experiment

To verify the results obtained above, we took a measurement of the phase and attenuation constants. Figure 7 shows the photograph of the fabricated leaky guide. Both values of the phase and attenuation constants were obtained by measuring $S_{21}$ between the launching and receiving ends of the line, for various values of line length. Figure 8 shows the measured results, indicated by the dots. The solid curve in this figure is the

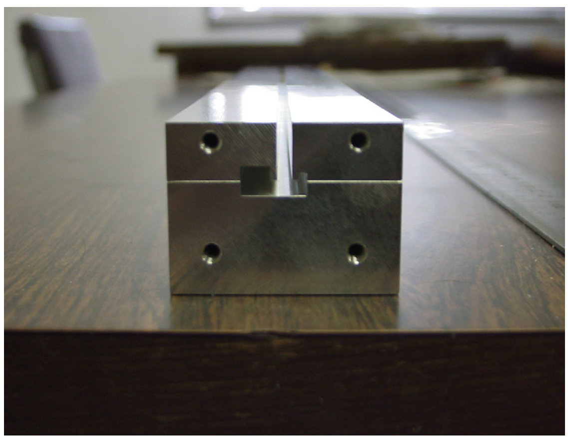

Fig. 7. Photograph of the fabricated guide.

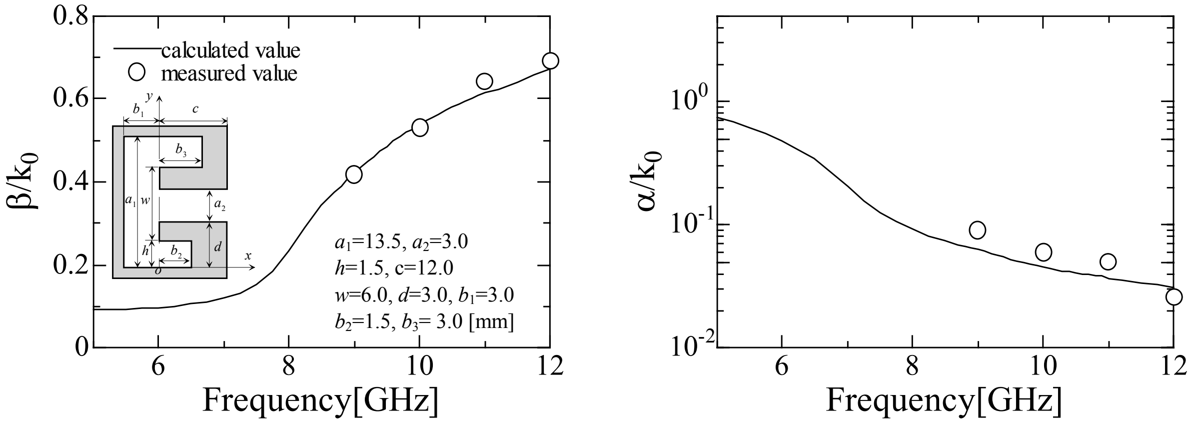


Fig. 8. Measurement of the normalized phase and leakage constants of the desired and the channel-guide leaky modes for the proposed guide as a function of the frequency.

theoretical result. Although there is a little difference between the theoretical and measured results in the attenuation measurement, the behavioral features of the stub-loaded ridge waveguide presented here are very similar each other. We also took a measurement of the radiation characteristics and these results will be presented at the talk.

## 5. Conclusion

We have proposed a new structure of the stub-loaded ridge waveguide for the single-mode operation. The usefulness of the proposed structure has verified numerically and experimentally. The design of the leaky-wave antenna with low sidelobe will be presented in near future. This work was supported in part by a Grant-in-Aid for Scientific Research (C) (13650439) from Japan Society for the Promotion of Science and by the Innovative Cluster Creation Project promoted by MECSST

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