LINEAR ARRAY OF RESONANT-TYPE LEAKY-WAVE ANTENNA BASED ON IMAGE NRD GUIDE

Ally Y. SIMBA*, Manabu YAMAMOTO*, Toshio NOJIMA* and Kiyohiko ITOH**

* Graduate School of Engineering
Hokkaido University
N13, W8, Kita-Ward, Sapporo 060-8628, Japan
E-mail: yamamoto@ice.eng.hokudai.ac.jp

** Tomakomai National College of Technology
Nishikioka 443, Tomakomai-shi
059-1275, Japan
E-mail: itoh@office.tomakomai-ct.ac.jp

1. INTRODUCTION

High performance antennas are required in millimeter-wave applications such as wireless LANs and car avoidance radar. A resonant-type leaky-wave antenna based on an image NRD guide is a good candidate for the microwave and millimeter wave systems[1], [2]. This is due to the ability to radiate in broadside direction with low sidelobe level and narrow E-plane pattern. Its H-plane pattern is, however, wide in comparison with that in the E-plane. An attractive approach to narrow the H-plane pattern and to enhance the gain is forming a linear array as shown in Fig. 1. In this paper a two-element linear array consisting of the resonant-type leaky-wave antenna and a rectangular waveguide is proposed and analyzed by using FDTD technique. Effective performance of the proposed array is confirmed by comparing its numerical results with that of single element case.

2. CONFIGURATION OF THE ARRAY ANTENNA

The structure of the antenna is shown in Fig.1. It is made of two equal elements. A metal trough is composed of parallel metal plates and an image plane. Each of elements is constructed the metal troughs and dielectric rods whose cross sections are rectangular. The open ends of the parallel plates with the same height form antenna apertures. This structure of the elements belongs to the class of an image NRD guide[1]. The antennas are fed by the longitudinal slots cut on the broad wall of the rectangular waveguide and on the image planes. The slots are staggered at 0.5mm in either side of the longitudinal axis with a distance $\lambda_g / 2$ apart, where λ_g is the guide wavelength for TE_{10} mode. The waveguide is terminated by a short-circuited at a distance $\lambda_g / 4$ from the center of the last slot, which

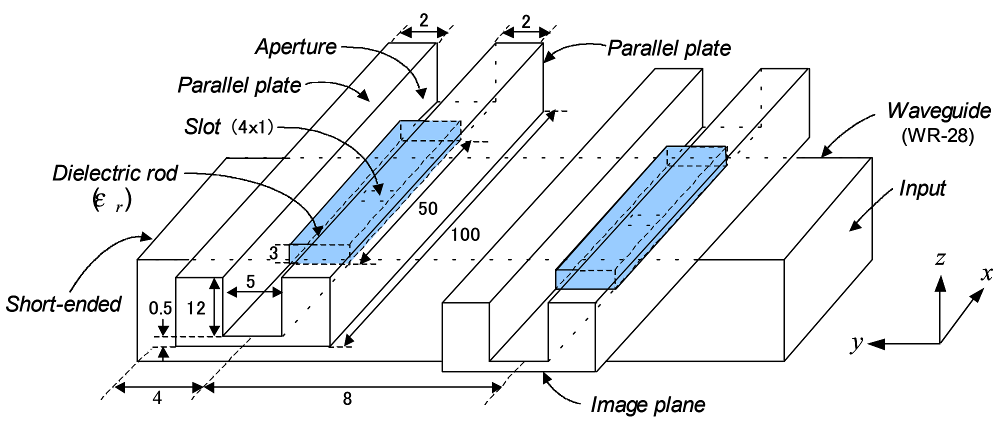


Fig. 1. A linear array of resonant-type leaky-wave antenna

makes the admittance in parallel with the last slot to be zero and hence improves the matching of the antenna. Thus the array is said to be standing wave fed and the elements are driven in phase [3].

The characteristics of the antenna were investigated by using FDTD method[4]. The structural parameters assumed in the analysis are shown in Figs. 1 and 2, where all dimensions are indicated in millimeters. The Yee cell, whose dimension is $\Delta x=\Delta y=\Delta z=0.5$mm, is used to model the antenna. PML[4] having 4 layers is placed at all boundaries of the FDTD problem space to absorb the radiated outgoing waves.

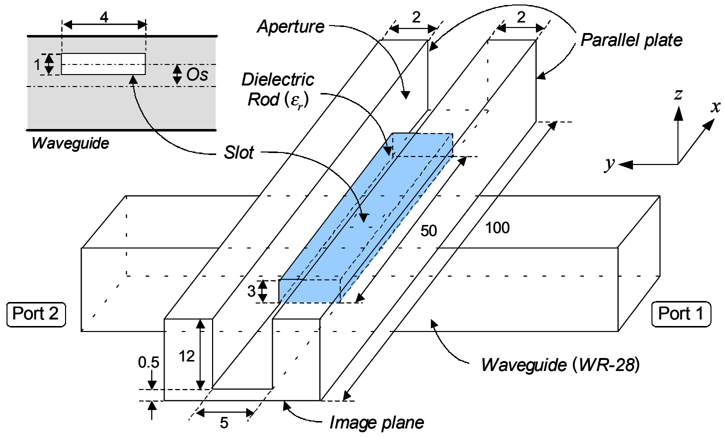


Fig. 2. Resonant-type leaky wave antenna fed by a slot cut in the broad wall of a wave guide.

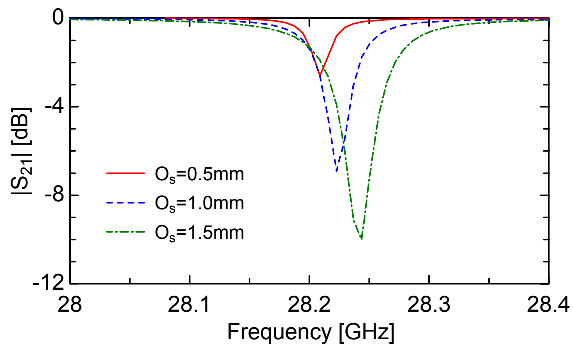


Fig. 3. $|S_{21}|$ as a function of slot offset.

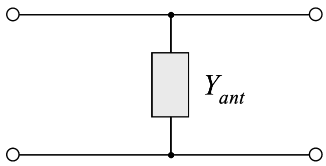


Fig. 4. Equivalent circuit (single-element).

3. SINGLE-ELEMET ANTENNA

In order to obtain the data used for the design of the array antenna, we first analyze the single-element antenna whose geometry is shown in Fig. 2. The analysis was carried out for the case of different offset length (0.5, 1 and 1.5mm). Fig. 3 shows the frequency dependence of $|S_{21}|$ as a function of the slot offset. It can be found that the coupling level between the antenna and the waveguide increase with the increase of the slot offset. The slot offset therefore provides a means for controlling the coupling level.

Contribution of the antenna to the waveguide is expressed as shunt admittance Y_{ant} as shown in Fig. 4. Fig. 5 shows the real part of the admittance Y_{ant} normalized by the wave impedance of the waveguide. The normalized conductance increases with the increase of the slot offset. This result implies that the antenna admittance can be also controlled by the adjustment of the slot offset. This is very useful feature for the design of the linear array shown in Fig. 1.

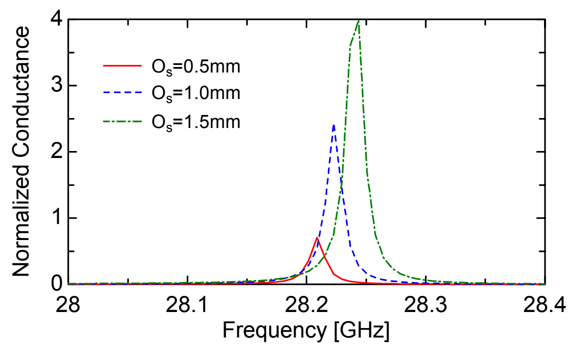


Fig. 5. Normalized antenna conductance.

4. 2-ELEMENT ARRAY ANTENNA

The equivalent circuit of the 2-element array is shown in Fig. 6. As can be seen from the figure, the total input admittance Y_{in} is equal to a double of the individual antenna admittance shown in Fig. 4. Considering the antenna conductance depicted in Fig. 5 at the resonant frequency of 28.21GHz, the 0.5mm offset length give the best matching condition compared with the other case.

The gain and return loss of the 2-element array with the slot offset of 0.5mm is investigated by using the FDTD analysis. The results are shown in Fig. 7 with solid lines. In Fig. 7(a), the gain of the array is compared with that of the single-element antenna where the port 2 is terminated with the matching load. Is can be found that the 2-element array exhibits higher gain than single-element case.

At the resonant frequency of 28.21GHz, the return loss of antenna array can be estimated as –15dB by using the results of Fig. 5 and equivalent circuit of Fig. 6. On the other hand, the return loss obtained by directly analyzing the array is observed as –12dB. Since the discrepancy between two results is small, it can be concluded that the mutual coupling between the adjacent elements is small. Fig. 8 shows the E- and H-plane patterns of single and 2-element array. The improvement of the beamwidth of the H-plane pattern for the 2-element array is observed. There is no change in the beamwidth for the E-plane pattern.

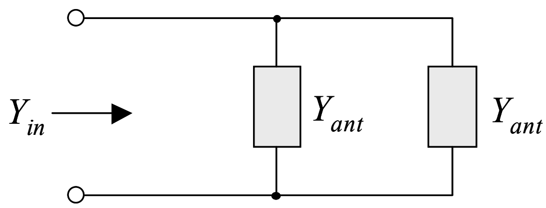
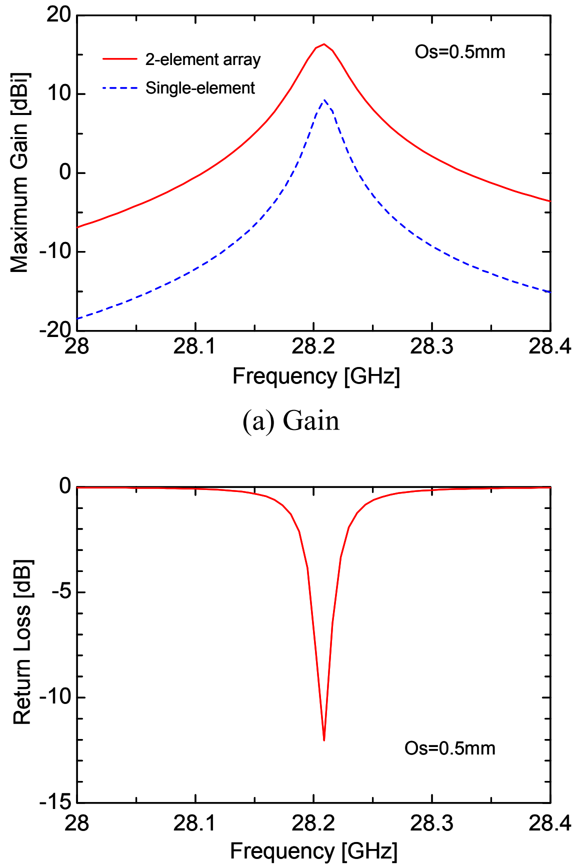


Fig. 6. Equivalent circuit of the 2-elemnt array.



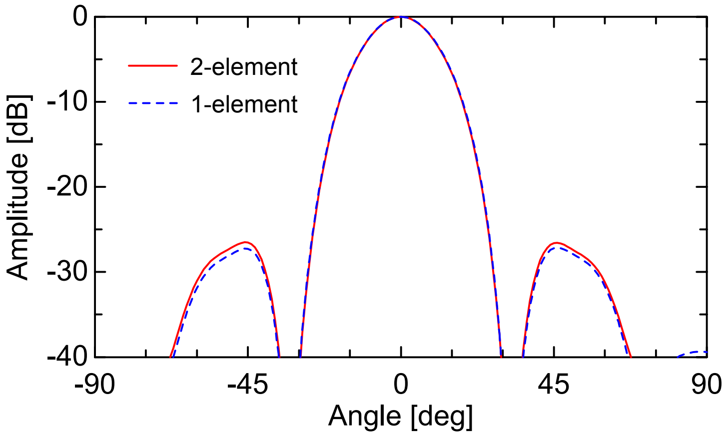
(a) Gain

(b) Return loss

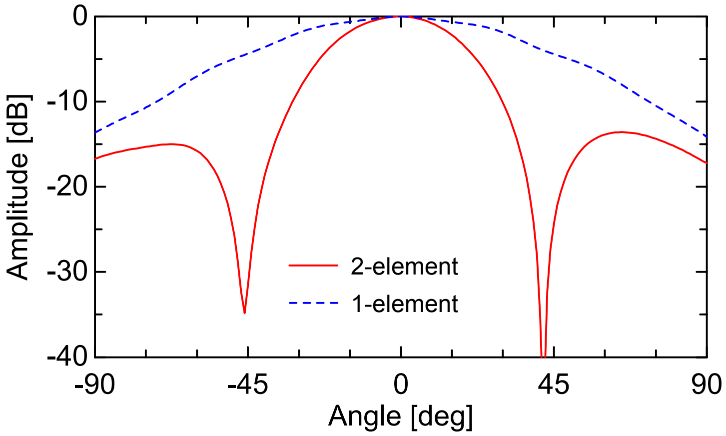
Fig. 7. Gain and return loss of the 2-elemnt array.

5. CONCLUSIONS

In this paper, 2-element linear array of the resonant-type leaky-wave antenna based on the image NRD guide has been proposed and analyzed by using the FDTD technique. First, single-element case was simulated to obtain the data used for the design of the array. Based on these results, the 2-element array was designed and analyzed. Numerical results confirmed the substantial increase in gain and the improvement of the H-plane pattern beamwidth with respect to the single-element case.



(a) E-plane pattern



(b) H-plane pattern

Fig. 8. Radiation patterns of the 2-element array antenna.

ACKNOWREDGEMENT

This work has been supported by Grant-Aid-for Research (A)(2) 11355017 from the Ministry of Education, Culture, Sports, Science and Technology of Japan.

REFERENCES

[1] M.Yamamoto and K.Itoh, "Resonant type leaky wave antenna using image NRD guide," Electron.Lett, vol. 35, no. 11, pp.857-858, June 1999.

[2] M.Yamamoto and K.Itoh, "Resonant type leaky wave antenna using image NRD guide," 1999 IEEE AP-S International Symposium, vol. 2, pp.800-803, July 1999.

[3] R.S. Elliot, Antenna theory and design. New Jersey, Prentice-Hall, Englewood, 1993

[4] A. Taflove, Advances in Computational Electrodynamics: The Finite Time Domain method. Norwood, MA, Artech House, 1998.