

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 $\Delta x=\Delta y=\Delta z=0.5\text{mm}$, 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.

3. SINGLE-ELEMENT 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.

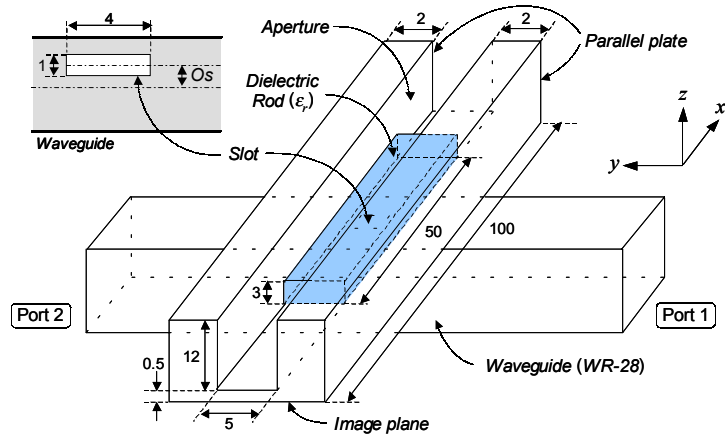


Fig. 2. Resonant-type leaky wave antenna fed by a slot cut in the broad wall of a wave guide.

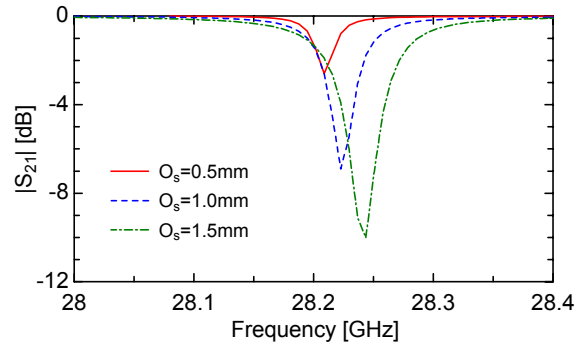


Fig. 3. $|S_{21}|$ as a function of slot offset.

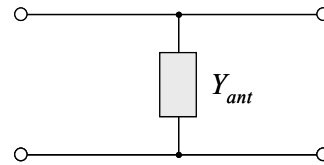


Fig. 4. Equivalent circuit (single-element).

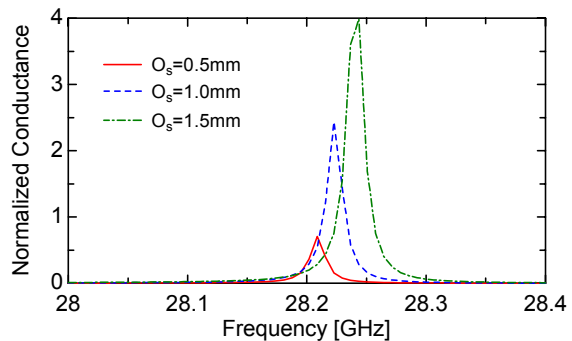


Fig. 5. Normalized antenna conductance.

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. It 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.

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.

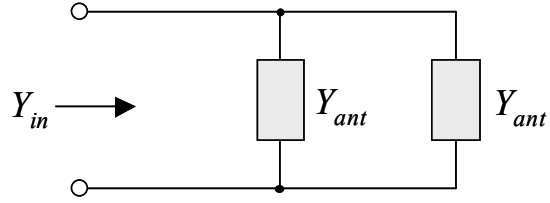
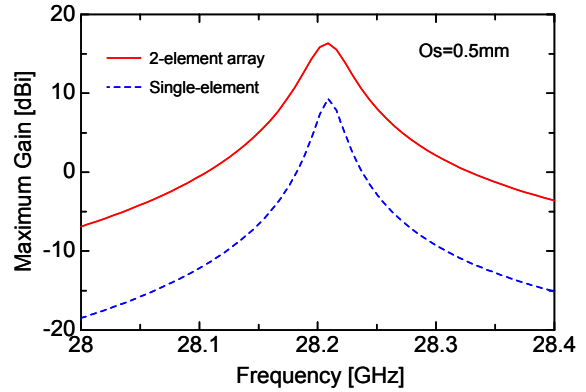
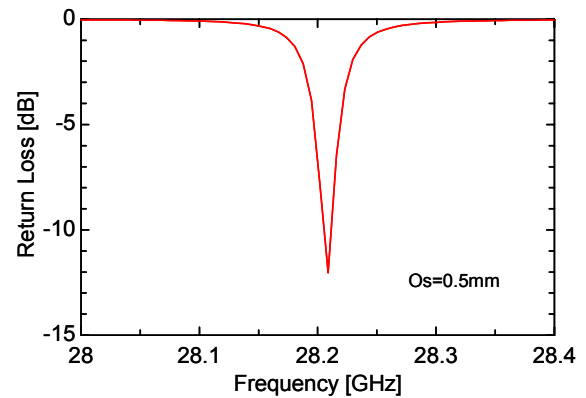


Fig. 6. Equivalent circuit of the 2-element array.

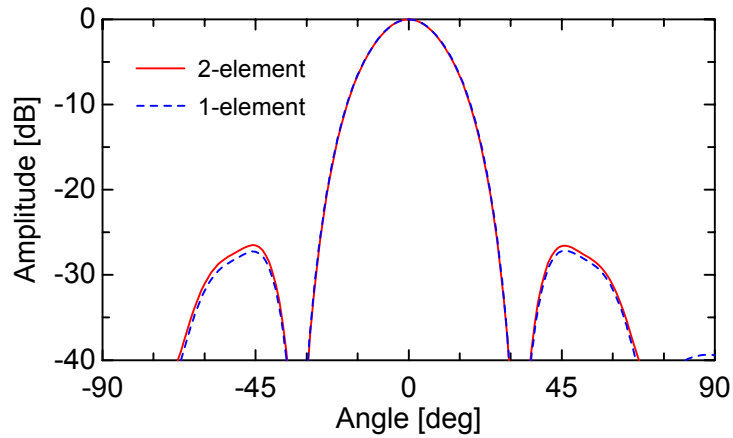


(a) Gain

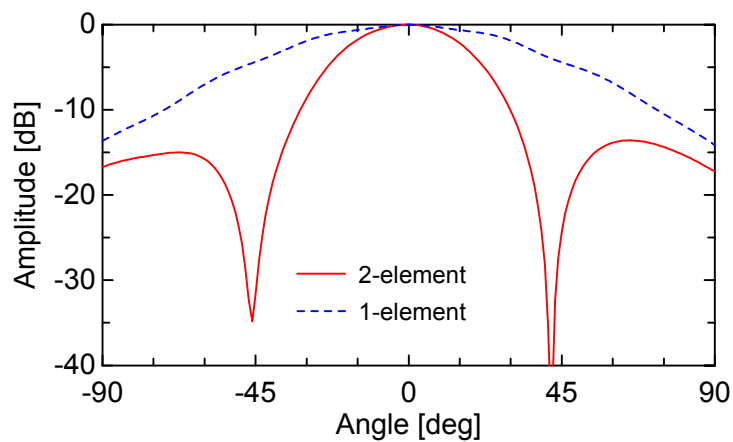


(b) Return loss

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



(a) E-plane pattern



(b) H-plane pattern

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

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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.