X-band Near-field Focusing Leaky-wave Antenna With Inhomogeneous Waveguide

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***Abstract*— We propose the near field focusing leaky-wave antenna using an inhomogeneous rectangular waveguide. The height of broad-wall is inhomogeneous to obtain focusing effect at the arbitrary position. We propose a design method of the inhomogeneous height of broad-wall of rectangular waveguide. Simulation results and measurement results at X-band are obtained to validate the proposed method.**

I. Introduction

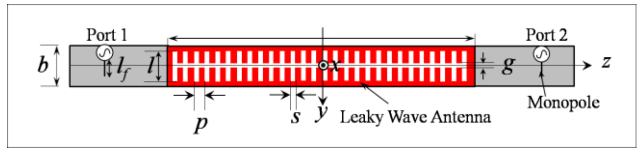
In recent years, security measures at airports and bay ports have become important. Dangerous goods such as bombs are miniaturized, easy to be carried and concealed. There is a high necessity of image technology capable of detecting non-contact / non-invasive hazardous substances etc. on the human body.

Technologies for focusing microwaves on the near field are drawing attention in various applications such as imaging, thermotherapy [1], WPT (wireless power transfer) [2], RFID reader [3]. The small and light handy type imaging device is desired to detect object on the surface of human body.

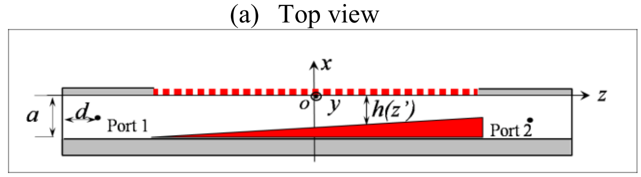
Normally, for the focal plane imaging, lenses or reflector are used. However, it is not suitable for compact device because the weight and size of lens or array increase. If focus effect can be obtained by using only an antenna, it is compact and possible to reduce the weight, and it is expected to be applied to realize the handy type imaging device.

In this research, we focused on the waveguide leaky-wave antenna which is one of traveling wave antenna with characteristic the radiation by changing the frequency. For the focusing effect using the waveguide leaky-wave antenna, using a tapered leaky-wave line source [4], the slot interval of the leaky-wave antenna is not uniform [5][6], but study of making the internal structure inhomogeneous of a waveguide has not been made.

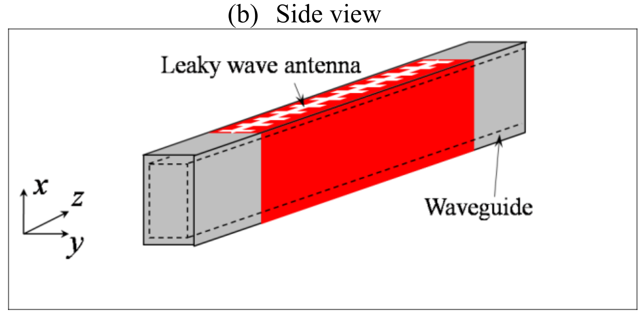
In this paper, a design method of the near field focusing leaky-wave antenna using the inhomogeneous rectangular waveguide is shown. To validate the proposal method, simulation results and measurement results are shown.



(a) Top view



(b) Side view



(c) Birds view

Fig. 1. Proposed waveguide focusing leaky-wave antenna

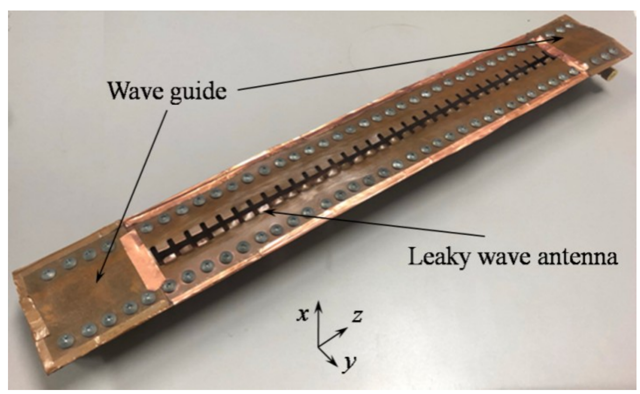


Fig. 2. The photograph of a prototype focusing leaky-wave antenna.

II. Design method

In order to perform imaging, radiation needs to be focused at the near field with the same frequency. One method of focusing leaky waves in the near field is to make the phase constant of traveling wave waveguide non-uniform. By gradually changing the phase constant, leakage radiation can be focused in the near field. In our design method, waveguide focusing leaky-wave antenna needs the desired phase constant distribution.

Fig. 1 shows the simulation model of waveguide leaky-wave antenna in this report. The waveguide leaky-wave antenna has many slots on the narrow-wall surface. The design frequency of this antenna is 10 GHz, the structure of the leaky-wave antenna part is based on the waveguide slot array of [6]. The wave is feed by a monopole exciting the TE10 mode. Parameters are a=28 mm b=14 mm L=300 mm p=9 mm s=3 mm l=14 mm g=3 mm d=8.86 mm l_f=7.2 mm.

Fig. 2 shows leaky-wave antenna our prototype. This antenna is composed the waveguide and the leaky-wave antenna. And both of the waveguide and the leaky-wave antenna are made of copper plates. The prototype waveguide focusing leaky-wave antenna connects the antenna and the waveguide with screws. Also, flanges are provided on both sides of the antenna to connect with screws. Many screw holes are provided on the flange to connect the waveguide and the antenna.

The radiation direction depends on h, height of broad-wall. Also, the phase constant is depended on the height of broad-wall. From this, it is possible to predict phase constant at each height of broad wall.

The relation between the phase constant distribution of the leaky-wave antenna and the height distribution of broad-wall is approximated. The relation approximation is shown in Equation (1).

$$h(z') \text{ [mm]} = e^{\frac{2611}{689} - \frac{10\cos^{-1}\beta(z')/k_0}{689}} \quad (1)$$

By using the Equation (1), it is possible to estimate the broad-wall height distribution $h(z')$ for focusing effect at an arbitrary position.

When the design focusing point is S (z_s [mm], x_s [mm]) = (250, 250), the desired phase constant distribution is shown in Fig. 3. As z increases, the desired phase constant distribution normalized by wave number gradually decreases. Also, simulation result gave same trend. Both of simulation and desired phase constant distribution are almost in agreement. The height of broad-wall distribution to focus S (250, 250) can be estimated by this phase constant distribution into Equation (1).

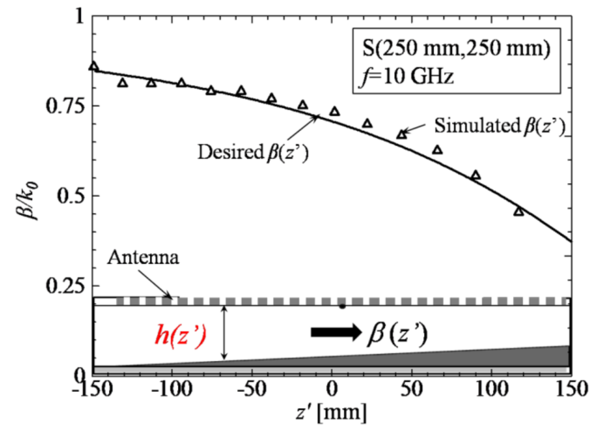


Fig. 3. Desired phase constant distribution for focusing when design point is z_s=250 mm,x_s=250mm.

III. EXPERIMENT

The electric field distribution of the prototype antenna is measured. A dipole antenna was used as a receiving antenna.

Fig. 4 shows the comparison of the electric field distribution between (a) simulation result and (b) measurement result. It is shown that focusing effect can be observed at the design focal area in both of the simulation result and the measurement result.

Fig. 5 shows the line distribution of electric field at x = 250 mm at white line of Fig. 4. In the simulation result, the maximum power density was observed z = 267 mm. In the measurement result, the maximum power density was observed z = 275 mm. These roughly agree with the design value of z = 250 mm.

IV. CONCLUSION

In this research, the design method of focusing leaky-wave antenna with inhomogeneous waveguide, the simulation results and the measurement results were shown. It can be estimated the height distribution of broad-wall to obtain focusing effect from the relation approximation.

Focusing effect was confirmed with both simulation results and measurement results. Both of the simulation results and the measurement results were roughly in agreement with the design value.

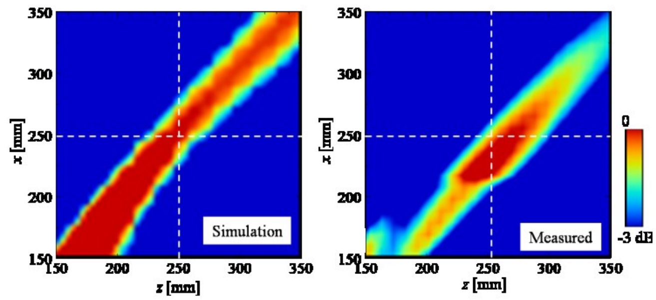


Fig. 4. Electric field distribution at 10 GHz when design point is *z*=250 mm, *x*=250mm.(a) Simulation and (b) Measurement. Measured area (150 < *z* [mm] <350, 150 < *x* [mm] <350).

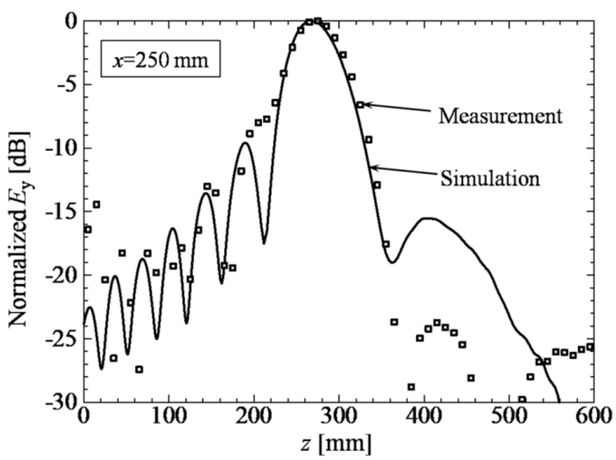


Fig. 5. Field line distribution at x = 250 mm (normalized with maximum intensity).

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