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.
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).

\[
h(z) [\text{mm}] = \frac{2611}{689} \cos^{-1} \frac{-1}{\beta(z)} \sqrt{\frac{d}{k_0}}
\]

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 \((z_0, x_0) [\text{mm}]\) =
\((250, 250)\), 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).

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, $x=250$ mm. (a) Simulation and (b) Measurement. Measured area ($150 < z \text{[mm]} < 350$, $150 < x \text{[mm]} < 350$).

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

REFERENCES


