Bistatic Millimeter-Wave Imaging Using Leaky-Wave Focusing Antennas

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***Abstract*— In this paper, an active millimeter wave-imaging system is proposed where detection of a target object is achieved by measurement of both the scattered and reflected fields. In the proposed system, two leaky-wave focusing antennas (LWFAs) are deployed in a bistatic setup and the capability of the proposed setup to detect and subsequently image a planar conducting target object is verified by measurement. It is shown that the object can be detected and the geometrical characteristics can be more clearly distinguished in the image generated from the reflected field.**

Keywords—Leaky wave antennas (LWAs), millimeter wave imaging, millimeter wave radar

I. Introduction

To address the challenges of high costs and limited portability in current millimeter wave imaging systems, an active millimeter wave imaging system based on a rectangular waveguide leaky-wave focusing antenna (LWFA) small enough to be operated by hand was proposed in [1]. The proposed system is based on the LWFA structure first proposed by our group in [2] where the focusing effect is achieved by tapering the phase constant of the travelling wave inside the waveguide by tapering the broadwall height distribution.

The system was shown to be able to detect and image dielectric and conducting objects positioned both in free space and in front of a relatively flat conducting surface such as the body phantom used in that case. This was attributed to the ability of the system to detect the scattered field from objects with an angle independent scattering pattern such as a cylinder as well as from the edge of planar objects. A problem with this setup, therefore, is the inability to detect planar objects with a width wider than that of the resolution of the LWFA as well as the inability to distinguish the geometrical characteristics of a scattering object which may be important for target recognition. To address these challenges, a setup using two of the LWFAs in a bistatic setup is proposed in this letter.

II. Imaging Sytem

The side view of the proposed concept is shown in Fig. 1 where a TE_{10} mode is excited at port 1 inside the waveguide structure of LWFA 1. The target object area at the focusing position is illuminated by the electric field radiated from LWFA 1 and both the scattered and reflected fields are measured by obtaining the transmission coefficients between the port 1 of LWFA 1 and port 3 of LWFA 2 which is denoted as $|S_{31}|$ using the setup in Fig. 2.

This work was partly supported by JSPS KAKENHI Grant Number 20K04515 and was partly supported by the Ministry of Internal Affairs and Communications in Japan (JPJ000254).

A disadvantage apparent from the setup is that imaging at only a single frequency is possible. In the system proposed in

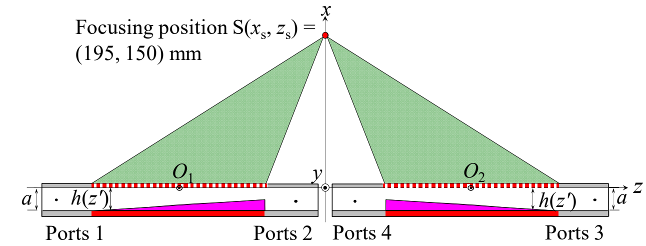


Fig. 1. Side view of the proposed concept.

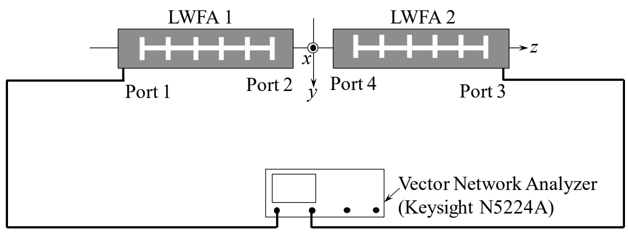


Fig. 2. Top view of experiment setup to measure the scattered and reflected field using leaky-wave focusing antennas (LWFAs).

[1], the frequency scanning capability of the LWFA was used to scan one dimension whereas the LWFAs were physically moved in the second dimension to generate a two-dimensional image of the target scene. Because the focusing position changes with frequency, it is not possible to use frequency scanning therefore the setup shown in Fig. 1 needs to be physically scanned in two-dimensions to generate a two-dimensional image.

III. Experiment and Discussion

To confirm the proposed concept, the experiment setup shown in Fig. 2 was used. In the experiment, the target object shown in Fig. 3 was used where the object was positioned with its centre corresponding to the focusing position of the LWFAs at S(x_s, z_s) = (195, 150) mm. To confirm the results of the proposed concept, the target object was first scanned using the system in [1] and the results shown in Fig. 4(a). The object was then scanned from $-90 \leq z \leq 90$ mm and $-45 \leq y \leq 45$ mm and the transmission coefficient $S_{31}(y, z)$ was measured for each position of the target object using the setup in Fig. 2 and the results are shown in Fig. 4(b).

From the results in Fig. 4(a), the target object can be observed which is because of scattering from the edges of the planar elements in the target object. However, the geometrical details of the object cannot be clearly observed. Additionally, should the object be replaced with a large planar object, it is anticipated that the object would not be detected in that case as the edge of the object would not be illuminated by LWFA \

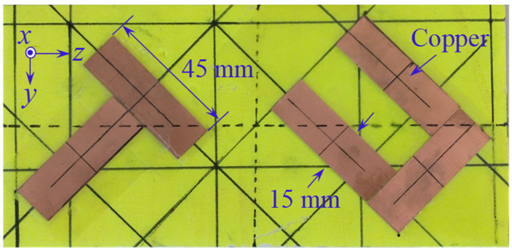
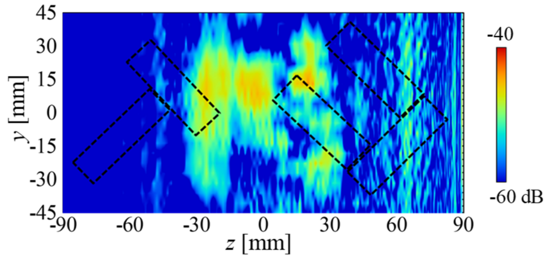
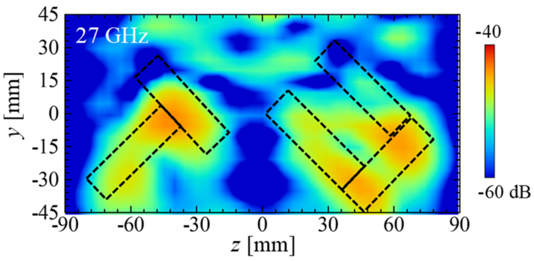


Fig. 3. Target object used in imaging experiment.



(a)



(b)

Fig. 4. Imaging results extracted from the (a) scattered field and the (b) reflected field.

1 and so the scattered field from the edge would not be detected by LWFA 2.

In the case of the reflected field image shown in Fig. 4(b), the geometric properties of the target object can be observed at 27 GHz which corresponds to the design frequency to focus on S thereby confirming the ability of the setup to measure the reflected field. However, apart from the requirement to scan the setup in two dimensions as discussed in section II, a further challenge is that the details of the object are smeared owing to depolarization of the scattered field from the object. It is therefore anticipated that should the object size be reduced, the y-component of the scattered field will be reduced which means that the object will not be detected by the y-polarized LWFAs. How to address this challenge, along with how to achieve scanning at one frequency, are the next step in this study.

IV. Conclusion

In this letter, a bistatic setup using two LWFAs was proposed to measure the reflected and scattered fields to allow the detection and subsequent imaging of planar dielectric and conducting objects. The proposed setup was verified by measurement where two-dimensional images of a target planar object were generated from both the scattered and reflected fields. In the case of the reflected field, the geometrical details of the object could be more clearly observed compared to the scattered field case confirming the capability of the proposed setup to measure the reflected field. A disadvantage of the setup is that mechanical scanning in two-dimensions is required which eliminates the advantage of scanning one dimension instantaneously by frequency sweep. How to approach this challenge will therefore be the focus of this study going forward.

References

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