Leaky-Wave Focusing Antenna With Modified Slot Array Antenna For Polarization Diversity

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***Abstract*— In this letter, a modified slot array antenna structure is proposed such that the polarization of the radiated electric field from a rectangular waveguide leaky-wave focusing antenna (LWFA) is shifted by 45°. It is shown that two settings using the proposed structure can be used such that the phase difference between the settings is about 90°.**

Keywords—Leaky wave antennas (LWAs), polarization diversity, slot array antenna, millimeter wave radar

I. INTRODUCTION

There has been increasing interest in recent years into millimeter wave imaging and radar owing to the many advantages offered by such technologies in the arenas of security and personnel scanning [1]. In current technologies, which primarily use the phase of the scattered field, the orientation of scattering objects is assumed to be the same as the polarization of the electric field illuminating the target scene during the reconstruction procedure [2] – [3]. This means that the ability of the proposed technologies to detect arbitrarily oriented objects aligned in directions different to the polarization of the transmitting and receiving antennas from only the magnitude of the scattered field is not a priority and is therefore worthy of consideration. Use of the magnitude of the scattered field greatly simplifies the image reconstruction process as time consuming reconstruction algorithms are not needed.

To accomplish the detection and subsequent imaging of scattering objects using the magnitude, a relatively portable leaky-wave focusing antenna (LWFA) based imaging system was proposed in [4]. Despite the promising results, a problem encountered was the inability of the proposed system to detect objects that are not oriented along the same direction as the polarization of the LWFAs. To address this challenge, a modified slot array antenna structure is proposed where a shifted component of the radiated electric field is obtained. Two settings using the proposed structure are also presented such that a phase difference of about 90° between the settings is demonstrated.

II. PROPOSED SLOT ARRAY ANTENNA STRUCTURE

In the previous slot array antenna structure used with LWFA 1 [4] as shown in Fig. 1, only the x-component of the electric field was radiated which means that only objects oriented along the same direction could be detected. In this structure, the x-component of the electric field is induced in the longitudinal slit running along the length of the antenna structure and it is this component that is radiated. The z-component is also induced in the shorter transverse slots across the width of the antenna. However, owing to the opposite phase difference of the induced components between the two branches on either side of the longitudinal slit, this z-component is cancelled out.

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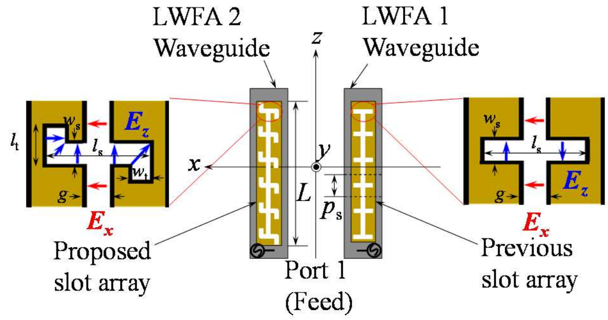

Fig. 1. Previous and proposed slot array antenna structures.

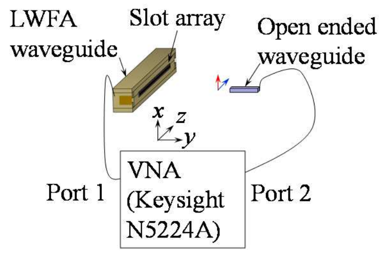

Fig. 2. Experiment setup to measure radiated component of electric field.

To allow the radiation of both the x and z-components of the electric field, an asymmetry is introduced to the structure as in LWFA 2 in Fig. 1 inspired by the design proposed by [5] and used by [6]. The optimal parameters of the proposed structure shown were found by Finite Difference Time Domain (FDTD) to be $l_s = 3.6$ mm, $l_t = 2$ mm, $w_s = 1$ mm, $t = 1$ mm and $g = 1$ mm such that the magnitudes of both the x and z-components are at almost the same magnitude at a selected design frequency. The length of the antenna is $L = 200$ mm and the pitch between each slot is $p_s = 3.6$ mm.

III. EXPERIMENT AND DISCUSSION

To confirm the radiated electric field from the proposed structure, the experiment setup shown in Fig. 2 was used where an open-ended waveguide (OEWG) was scanned at $y = 195$ mm along the z-direction above the LWFA using a motor with $y = 0$ mm corresponding to the surface of the LWFA. The magnitude of the transmission coefficient ($|S_{21}|$) between the LWFA with the previous and proposed slot array structures and the OEWG was measured for each position along the z-direction and the results are shown in Fig. 3.

From the results, the radiated x and z-components of the electric field are at almost the same magnitude in the proposed structure at the chosen design frequency of 26 GHz. However, the z-component in the previous design is about 20 dB

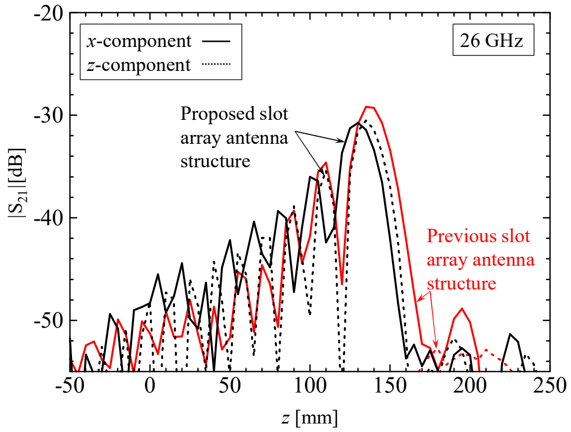

Fig. 3. Measured transmission coefficient between OEWG and LWFA with previous and proposed slot array antenna structure.

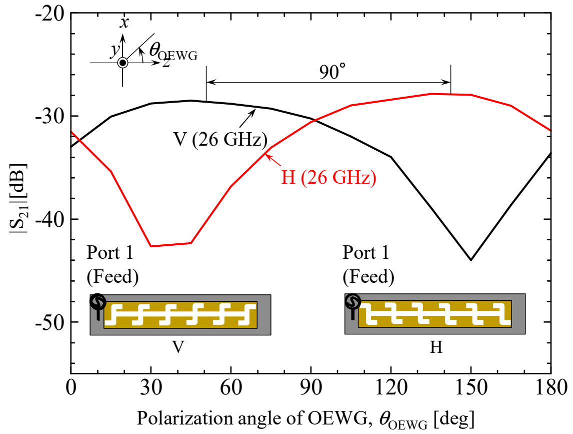

Fig. 4. Measured transmission coefficient between between OEWG and LWFA for different polarization angles of OEWG θ_{OEWG}.

lower than the *x*-component. From these results, we can conclude that at 26 GHz, the radiated electric field from the LWFA with the proposed slot array antenna structure has been shifted to 45° along the *xy*-plane.

Two settings using the proposed antenna structure were then measured and are denoted as horizontal (H) and vertical (V) which correspond to the polarization of the radiated electric field along 45° and 135° respectively. These settings are shown in Fig. 4. To confirm the phase difference between these V and H settings, the same experiment setup shown in Fig. 2 was used however in this case the LWFA with the proposed slot array antenna structure in V and H settings were held stationary. The OEWG was positioned at (y, z) = (195, 140) mm and rotated around the *xz*-plane and the $|S_{21}|$ measured for each angle θ. This position was selected because it was the focusing position of the LWFA [4] and because this position corresponds to the focusing position of the LWFA at 26 GHz as can be observed from Fig. 3.

The results of this experiment are shown in Fig. 4 where it was observed that at θ_{OEWG}= 45°, the radiated electric field from the V setting is strong whereas at θ_{OEWG} = 135°, the radiated electric field from the H setting is strong at 26 GHz with a difference of about 14 dB between the peaks and valleys in each case. These results therefore validate the usefulness of the proposed slot array antenna structure design when applied in a polarization diversity setup.

IV. Conclusion

In this letter, a modified slot array antenna structure design is proposed to obtain a 45° shifted component of the radiated electric field. Two settings denoted as V and H using the proposed antenna structure were also presented where it was shown that it was possible to obtain radiated components of the electric field using the LWFA with a phase difference of about 90° between them. The presented structure and setting could therefore be used for imaging purposes where the LWFA antennas could be deployed in a polarization diversity and imaging techniques such as polarimetric filtering could be used to further improve image quality. A disadvantage of the proposed antenna structure is only a single frequency can be used for imaging as the fixed length of the slot would mean that cancellation of the induced components in the slots would still happen should the frequency be changed. This means, therefore, that the advantage of frequency scanning capability of the previously proposed LWFA based imaging system to scan one dimension is negated. How to address this challenge will therefore be the focus of this study going forward.

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