45° Polarized Slot Array Antenna with Differential Dual-End Feeding Network for Vehicle Applications

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***Abstract*— A 45° linearly polarized slot array antenna with differential dual-end feeding network is proposed in this paper, using substrate integrated waveguide (SIW) technology and single layer printed circuit board (PCB) process. Conventional radiation unit with one 45° inclined slot and two reflection cancelling vias is adopted in the proposed array, with its dual-end feeding potential exploited. Differential dual-end feeding network is applied to the one dimensional subarrays, in order to obtain a stable broadside radiation and a wide operating bandwidth. A simple filtering structure is integrated in the feeding network to reduce out-of-band monopulse radiation. A prototype array antenna with 4 × 4 radiation units at 24 GHz for vehicle applications is designed and fabricated to validate the design. Experimental results on reflection coefficient, gain, and radiation patterns are consistent well with simulation predictions. The prototype array antenna can operate from 23.9 GHz to 24.9 GHz (4 %) with its reflection coefficient under -10 dB and its gain varied from 14.5 dBi to 16.5 dBi. The main beam is stable at broadside with a maximum gain of 16.4 dBi at 24.5 GHz.**

***Keywords*—45° polarization, array antenna, differential dual-end feeding network, substrate integrated waveguide (SIW).**

I. INTRODUCTION

Slot array antennas has been intensively investigated and widely utilized in modern wireless communication systems for decades, with theories accumulated to guide the antenna design. With the help of substrate integrated waveguide (SIW) technology, planar integrated slot array antennas fabricated in low cost printed circuit board (PCB) process can be realized, which are perfectly suitable for microwave and millimeter-wave systems [1].

Previous researches on SIW slot array antennas are mainly focused on horizontally/vertically linear or circular polarizations [2]-[3]. However, 45° linearly polarized antennas also have many potential applications in modern systems, such as vehicle radar systems. The interferences from the opposite direction can be eliminated effectively by simply employing 45° polarization antennas, due to the polarization isolation between the transmitted signals and the interferences [4].

Among previous studies on 45° linearly polarized slot array antennas, 45° inclined slots etched on the broad wall of the waveguide are the most common radiation units [5]-[11]. One dimensional array with identical radiation units are usually fed in series for a simple feeding network. Then the one dimensional array can be fed by single-end feeding network, center-end feeding network, or dual-end feeding network. In case that all the radiation units are excited in the same phase, reflections from all the radiation units can be added up at the feeding port and result in a worse performance. Various methods have been proposed to solve the problem. Reflection cancelling vias are added solely or in pairs to the scanning array antenna, obtaining an enhanced operating bandwidth [5]-[8]. The -10 dB impedance bandwidth up to 7.5 % can be obtained in the scanning arrays [8], but the gain bandwidth is much smaller. Alternative slot pairs are adopted in the standing-wave array antennas and stable broadside radiations can be realized with the sacrifice of the operating bandwidth [9]-[11]. The -10 dB impedance bandwidth is 3.6 % and 2.88% in [9] and [11], respectively.

A 45° linearly polarized slot array antenna with balanced dual-end feeding network is presented in [12]. Stable broadside radiation and relatively wide operating bandwidth of 4.5% is realized with the sacrifice of antenna size. In this paper, a differential dual-end feeding network integrated with a simple filter is utilized in a larger array. Compact size, modestly wide operating bandwidth, stable broadside radiation, and flat gain performance can be realized. This paper is organized as follows. In section II, design concerns of the radiation unit and dual-end feeding network will be described. In section III, both the simulated and experimental results on reflection coefficient, gain, and radiation patterns will be provided and discussed. Finally the conclusion will be made in section IV.

II. DESIGN OF THE PROPOSED ARRAY

Design of the radiation unit and differential dual-end feeding and filtering network will be described in this section. All the simulations are done using Ansoft HFSS with conductor and dielectric losses taken into consideration. The microwave substrate used in the paper is Rogers 5880 with dielectric constant ε_r=2.2 and thickness h=0.508 mm. The thickness of copper layers is h_m=0.036 mm.

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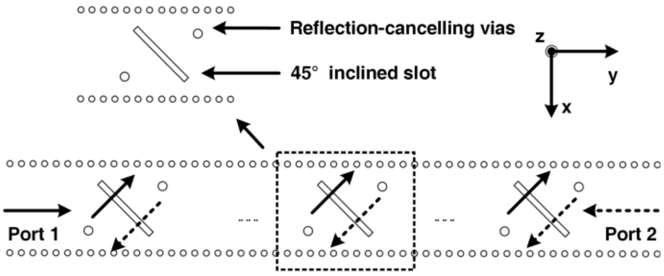

Fig. 1. Radiation unit and feeding scheme of one-dimensional subarray.

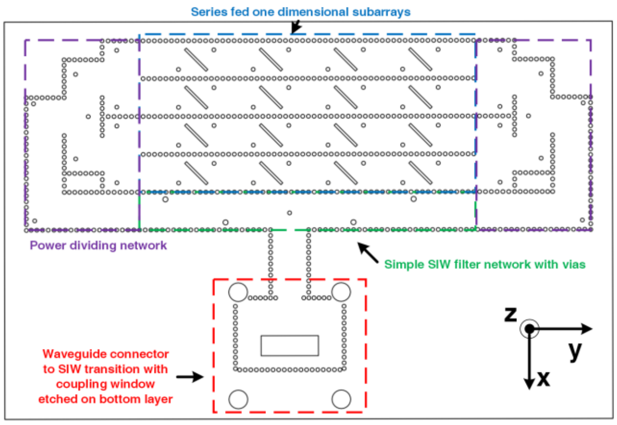

Fig. 2. Configuration of proposed array antenna.

A. *Radiation unit*

The radiation unit in the proposed antenna array consists of one 45° inclined slot etched on the top metal layer of the SIW transmission line and two reflection cancelling vias placed around the slot, as shown in Fig. 1. The conventional structure has been discussed and analyzed in [11]. Reflection cancelling vias are added in pair since the radiation unit is excited from both directions.

B. *One dimensional subarray*

The radiation units are usually connected in a series way to achieve a compact and simple feeding network, as shown in Fig. 1. Considering the one dimensional subarray, it can be excited using three different feeding networks, the single-end feeding network, dual-end feeding network, and center-end feeding network.

For the antennas with single-end or center-end feeding networks, the feeding ports without excitations are supposed to be shorten to ground. Scanning antennas can be realized using single-end feeding network, while nonscanning antennas can be obtained with either single-end or center-end feeding network. Nonscanning antennas with single-end feeding network are standing-wave slot array antennas, with an inevitable narrow operating bandwidth. Nonscanning antennas with center-end feeding network can be realized with traveling-wave propagation, but an extra slot coupling excitation using multi-layer configuration is needed. Thus, the dual-end feeding

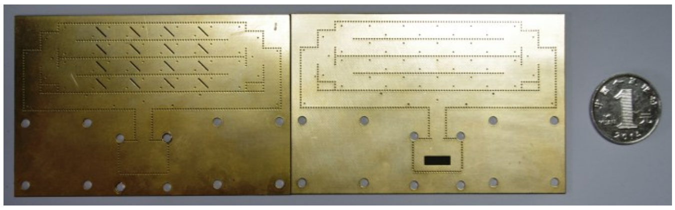

Fig. 3. Photograph of the proposed array antenna.

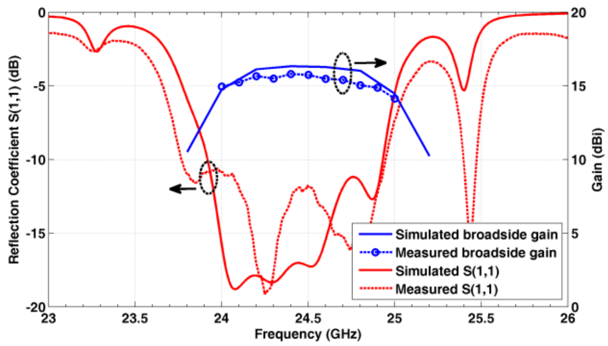

Fig. 4. Simulated and experimental results on reflection coefficient and gain of the proposed array antenna.

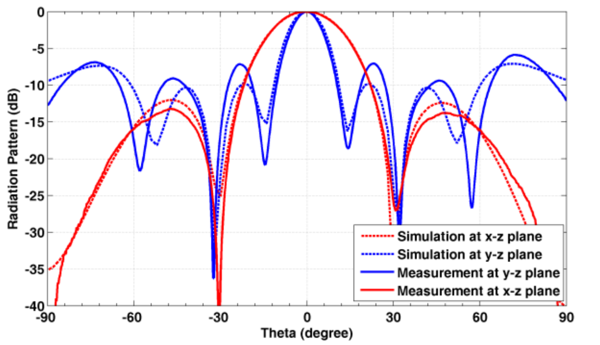

Fig. 5. Simulated and experimental radiation patterns at 24.5 GHz of the proposed array antenna.

network becomes the best choice for nonscanning antennas since travelling-wave propagation can be utilized to achieve a stable broadside radiation and a relatively wide operating bandwidth of both the impedance and the gain.

Dual-end feeding networks can be classified into balanced feeding network and differential feeding network. Assuming the feeding ports are equally distant from the center of the subarray, radiations of the units excited by the two feeding ports will cancel each other if balanced feeding network is employed as shown in Fig. 1. Thus differential feeding network is preferred and adopted in the proposed antenna design.

C. *Proposed array*

The proposed array antenna is a two dimensional array, as shown in Fig. 2. SIW power dividers are utilized to achieve parallel and identical excitations to the subarrays. Differential excitations of the two ports are realized by offsetting the T-junction of the outmost power divider from the center. Transition circuit from the waveguide connector to the SIW feeding line is designed and added to the prototype antenna array, in order to measure the prototype antenna.

It is also worthy to mention that the proposed array could turn into a monopulse radiation condition at a lower frequency, since the same phase excitations of the radiation units from both ends are no longer available. In order to reduce the undesired monopulse radiation, a simple filter structure with vias is added to the outmost power divider, as shown in Fig. 2.

III. RESULTS

A prototype array antenna with 4 × 4 radiation units is designed and fabricated to validate the proposed design, with its photography shown in Fig. 3.

Simulated and experimental results of the prototype array are provided, with reflection coefficient and gain shown in Fig. 4 and radiation patterns at 24.5 GHz provided in Fig. 5. The prototype array antenna can achieve a stable broadside radiation with 45° linear polarization from 23.9 GHz to 24.9 GHz (4 %) with its reflection coefficient under -10 dB and its gain varied from 14.5 dBi to 16.5 dBi.

IV. CONCLUSION

Differential dual-end feeding network is employed in the slot array antenna to generate a stable broadside radiation with 45° linear polarization for the first time. A simple filter structure with vias is integrated into the feeding network to reduce the undesired monopulse radiation. A prototype antenna with 4 × 4 radiation units is fabricated and measured. Good agreement between the simulated and measured results can be achieved, validating the design method and providing a potential method to realized 45° linearly polarized antenna with good performance.

ACKNOWLEDGMENT

The authors would like to thank T. Y. Huo with the State Key Laboratory of Millimeter Waves, Southeast University, Nanjing, China, for his kind help in prototype fabrication.

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