# Millimeter-Wave Slot Array Antenna Using SIW and Electroforming Techniques

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***Abstract*-In this paper, two types of slot array antennas are introduced and summarized for millimeter-wave applications. The substrate integrated waveguide (SIW) technology is applied to design 45°-inclined series radiating slots for Ka-band. In addition, the design method has been verified by a linear and a planar slot array application. Lastly, the conventional W-band slot array antenna is fabricated using electroforming technique and the high radiation efficiency is obtained from its high fabrication accuracy.**

## I. INTRODUCTION

Waveguide slot array antennas are attractive candidate for millimeter-wave applications because of their high radiation efficiency and low-profile feature for system integration. As a result, slot array antennas are widely used for military and commercial applications such as detection radars, broadcast satellites, and wireless communications. In addition, the precise and reliable manufacturing technique is one of the most important things especially for large-scale array antennas. The representative technique based on printed circuit board (PCB) manufacturing process is substrate integrated waveguide (SIW) and it has been widely applied for various millimeter-wave antenna researches [1]. Recently, the electroforming technique is applied for W-band slot array system with high antenna efficiency of 81.9% at center frequency of 94 GHz [2]. From Section II, two manufacturing examples are introduced for slot array antenna applications and summarized in Section IV with conclusion.

## II. SUBSTRATE INTEGRATED WAVEGUIDE (SIW) SLOT ARRAY ANTENNA

The design method for 45°-inclined series slot array antenna was suggested in [3]. Based on the operating center frequency and relative permittivity of a PCB, the diameter($d$) and the spacing($s$) of via-hole arrays are determined to minimize radiation and conductor loss of SIW transmission line in the Ka-band (see Fig. 1). The alternating reactance slot pair and its equivalent circuit as a basic radiating unit for 45° linear polarization as shown in Fig. 1 can be extracted from a single SIW slot module with respect to their resistance and reactance characteristics. The uniformly excited 16 series slot array antenna example of [4] is verified with equivalent circuit and full-wave analysis, and experimental results. The magnitude and phase of all radiating slots with half guided-wavelength spacing are calculated using recursive impedance and current formulas and confirmed with full-wave simulation results. The fabricated linear slot array antenna is shown in Fig. 2. Moreover, the excitation control method for low sidelobe is

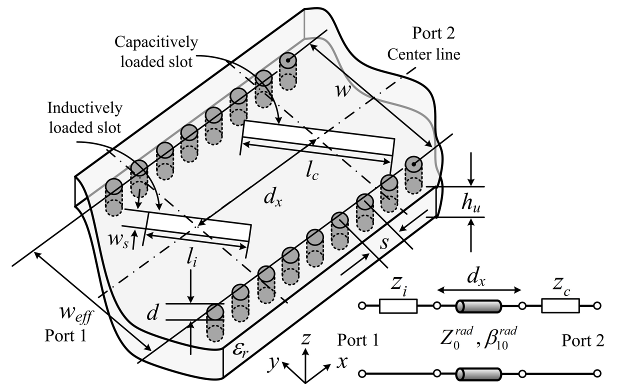


Fig. 1. The alternating reactance slot pair etched on the broad wall of a radiating SIW and its equivalent circuit, where $Z_0^{rad}$ is the wave impedance and $\beta_{10}^{rad}$ is the propagation constant of the $TE_{10}$ mode [3].

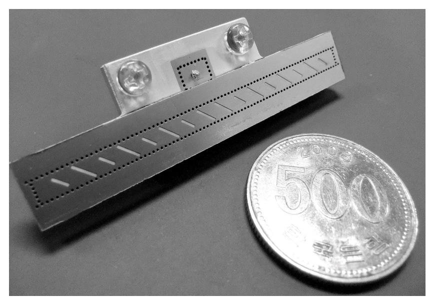

Fig. 2. The fabricated linear slot array antenna for Ka-Band [4].

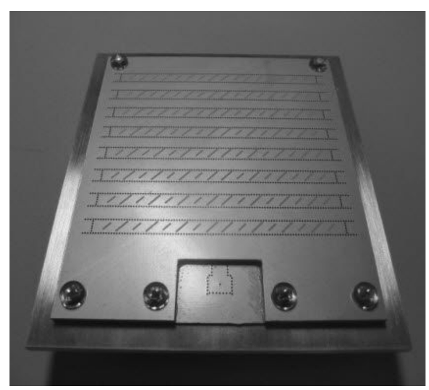

Fig. 3. The fabricated planar slot array antenna for Ka-Band [3].

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suggested and verified with Dolph-Chebyshev distribution for –20, –26 dB sidelobe levels in the Ka-band [5].

The planar slot array antenna design procedure including feeding network design is specifically introduced in [3]. The uniform field distribution and impedance matching from a feed point are achieved by series-to-series coupling slot design. As a result, the maximum gain and the aperture efficiency are obtained with of 24.3 dBi and 53.7 %, respectively. In addition, the proposed 45°-inclined series slot array design method are applied to the ±45° dual linear polarized slot array antenna with low mutual coupling [6] and the Ku-band monopulse antenna system [7].

## III. Electroforming Slot Array Antenna

It was found that the dielectric loss of the feeding network and unintended etching errors from radiating slots distort the aperture field distributions severely in terms of their amplitude and phase due to the relative permittivity of the PCB. It is clear that a simple hollow-waveguide slot array is favorable for high-efficient millimeter-wave antenna design.

The hollow waveguide transmission lines including feeding network can be modeled by mandrel made of aluminum. Next, copper is coated on the mandrel through electrodeposition in a plating bath, and then the mandrel is chemically resolved. The fabricated 8 × 8 slot array antenna for 94 GHz operation is shown in Fig. 4. All lengths and offsets of radiating slots are determined for uniform field distribution and impedance matching considering the external mutual coupling compensation. The simulated and measured reflection coefficients are compared in Fig. 5 and in good agreement with each other. In addition, the radiation patterns at center frequency of 94 GHz are compared in Fig. 6 for E- and H-plane, respectively. The measured maximum gain is 26.8 dBi at 94 GHz and the corresponding antenna efficiency is 81.9% for a given aperture.

## IV. Conclusion

Statistically, the frequency error between the simulation and the measurement for the SIW fabrication is within 2% in the Ka-band application [3, Fig. 19]. It is necessary that the compensation of the length and the width for both of the radiating and the coupling slots, simultaneously, should be included in the fabrication process, then more accurate frequency response can be achieved. In addition, the frequency response of the electroforming technique is fairly accurate even for the W-band application.

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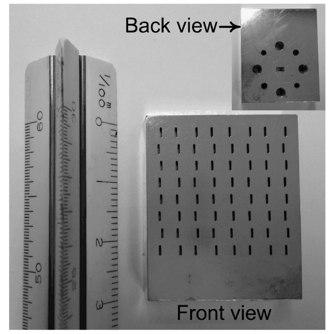



Fig. 4. The fabricated W-band 8 by 8 slot array antenna using electroforming technique [2].

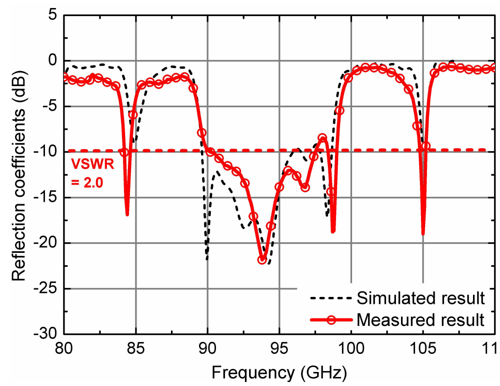
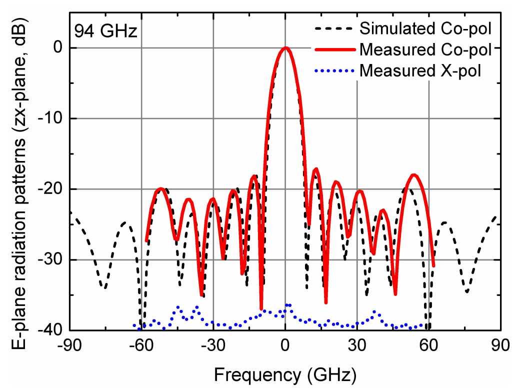
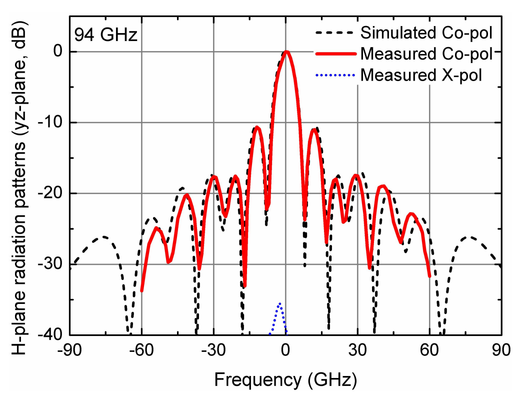



Fig. 5. The reflection coefficient [2].




(a)




(b)

Fig. 6. The radiation patterns (a) E-plane, (b) H-plane [2].

45°-inclined SIW resonant series slot array antenna for Ka-band," *IEEE Antennas Wireless Propag. Lett.*, vol. 10, pp. 318–321, 2011.
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