

60-GHz Substrate Integrated Waveguide-fed Transverse Aperture Antennas

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1. Introduction

Waveguide slot arrays have been intensively used in a variety of wireless systems because of their compact structures, large power capacity, high efficiency, and high reliability. The resonant and non-resonant longitudinal slot, inclined slot, and transverse slot have been long studied [1-3]. Up to now, waveguide longitudinal slot arrays have been extensively analyzed and the most frequently used for their compact structure and pure linear polarization [4-8]. However, the operation bandwidth of a waveguide slot antenna array is quite limited, which can be improved using a sub-array feed, a dielectric-slab partially filled waveguide, and a wide slot [10-12].

The substrate integrated waveguide (SIW) is one of waveguide which is formed using thru-via arrays in substrate. As a usual waveguide, slot antenna arrays are also formed on SIW [13-15]. However, the small waveguide height, high-permittivity dielectric of SIW and strong mutual coupling between slots narrow impedance bandwidth to about 3%. A ridge SIW slot antenna array has enhanced the impedance bandwidth up to 8.8% [16].

Recently, wideband SIW slotted narrow-wall-fed antenna arrays were proposed for the applications of 60-GHz millimeter-wave systems. The antenna can be fabricated on a single layered printed circuit board (PCB). A dielectric-loaded substrate integrated cavity (SIC) is coupled through the slotted narrow-wall of a feeding SIW. A slot is cut from the upper surface of each SIC as a radiator. As a result, the operating bandwidth of slot antenna backed by an SIC has been increased to 11.7% [17].

In this paper, the transverse aperture etched onto the broad-wall of an SIW is proposed and investigated for bandwidth enhancement at 60 GHz bands. The impedance bandwidths, radiation patterns, and gain of the single transverse aperture antenna fed by an SIW through an inserted inductive window are simulated and optimized at 60 GHz. Finally, a transverse aperture array is designed and measured.

2. Antenna Design

Fig. 1 shows the geometry of the transverse slot. A transverse slot with a length of L_s and width of W_s is etched onto the broad-wall of an SIW, which is backed by a via-formed cavity of the dimensions of L_c and W_c . The cavity is fed by an SIW through an inserted inductive window of a width of W_w

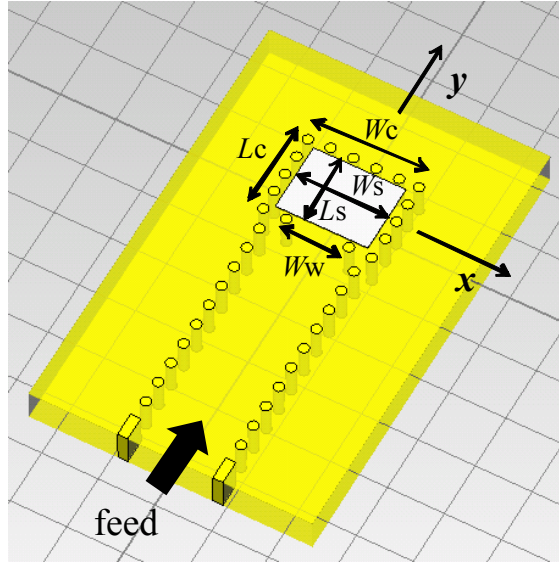


Figure 1: Proposed antenna

The proposed antenna is designed on a 0.635-mm thick RO3006 substrate of a dielectric constant of $\epsilon_r = 6.15$ and loss tangent of $\tan\delta = 0.0025$. The SIW is formed by through-vias with the conditions of $D_1/P \geq 0.5$ and $D_1/\lambda_0 \leq 0.1$. The width of the feeding SIW and the diameter of the metallic vias are fixed as $W_{\text{siw}} = 1.5$ mm and $D_1 = 0.2$ mm, respectively. The size of ground plane is 10 mm \times 6 mm. The antenna is designed and optimized using CST, a full wave electromagnetic field simulation tool.

Fig. 2 shows the simulated return loss of the proposed antenna. From the simulated results, it is seen that there are two resonances at 59.2 and 62.8 GHz for the proposed aperture antenna. An impedance bandwidth for 10dB return loss is about 11.6%, which is twice that of a conventional narrow slot. The radiation patterns in both E and H-planes show the typical radiation from a conventional slot antenna and with very low cross polarization levels. The slight beam squinting patterns in the E-plane are caused by the asymmetric feeding structure and limited groundplane size. The achieved gain is 7.4 dBi @ 59.2 GHz and 7.9 dBi @ 62.8 GHz, respectively.

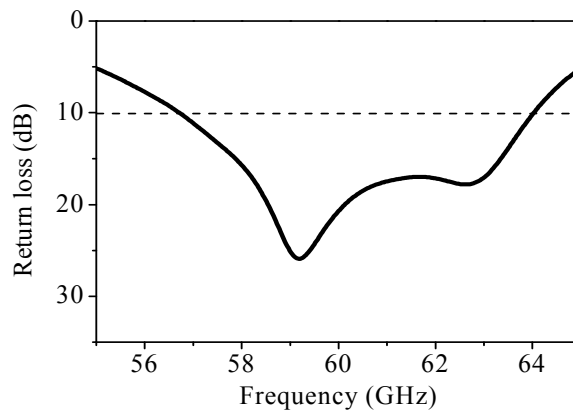


Figure 2: The simulated return loss of the SIW transverse single aperture antenna fed by an inductive window. $W_c = 1.95$ mm, $L_c = 1.47$ mm, $W_s = 1.65$ mm, $L_s = 1.17$, $W_w = 1.13$ mm, ground plane with width of 6 mm and length of 10 mm.

3. Antenna Array

An SIW transverse aperture antenna array was designed and prototyped on the RO3006 substrate using PCB technology at 60 GHz bands. The proposed 2×4 antenna array consists of 2×4 SIW transverse aperture elements and a compact eight-way tree-shape power divider [17]. The power divider splits the power into eight ways equally to excite all the elements in-phase. The width of the SIW divider is equal to the feeding SIW for each element, and the divider shares part of vias with the elements to keep the antenna array compact. The antenna arrays are excited by a WR-15 waveguide through a stepped waveguide-to-SIW transition is employed. With ratio of width to length 0.71, the spacing between elements are $L_x = 3.45$ mm ($0.69\lambda_0$), $L_y = 3.37$ mm ($0.674\lambda_0$), respectively, where λ_0 is the wavelength at 60 GHz in free space.

Fig. 4 shows the measured return loss of these arrays with the waveguide-to-SIW transition. The measured return losses follow the trend of the simulated ones well with a slight frequency shifting which may be caused by the fabrication tolerance and the permittivity fluctuation. The photos of the front and back view of the prototype are also shown in Figure.

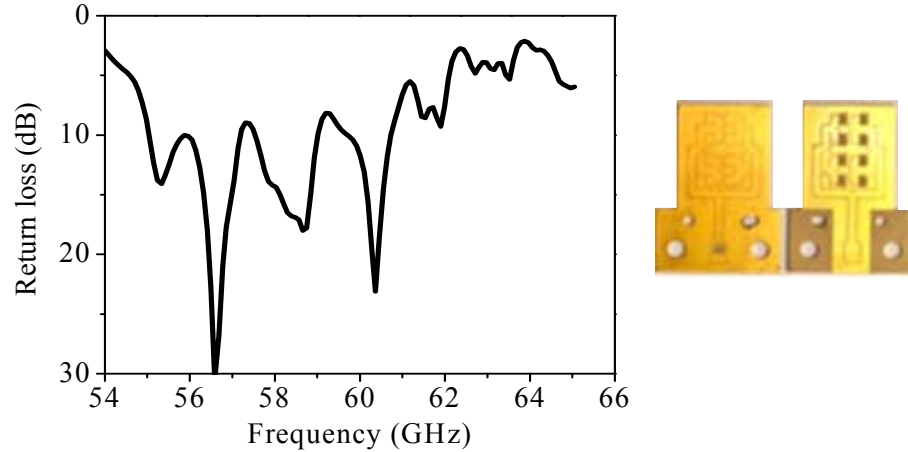


Figure 3: The measured return loss of the proposed SIW transverse aperture antenna array fed by an inductive window, as well as photos of front and back views of the prototype.

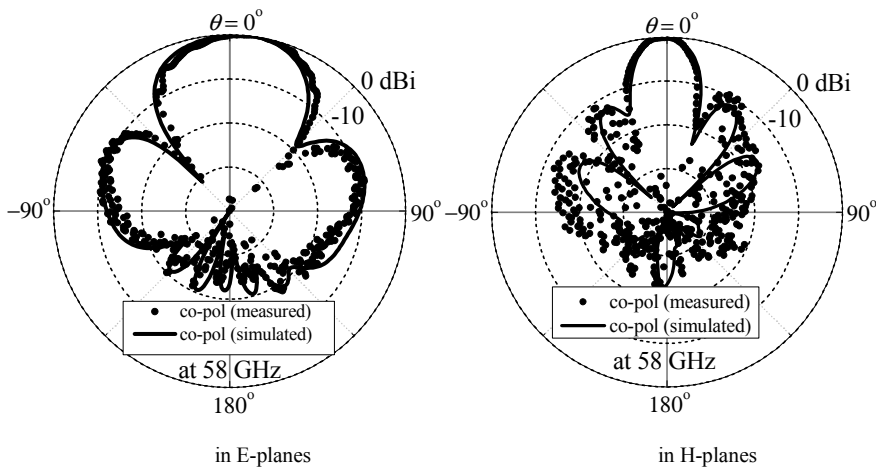


Figure 4: The normalized measured radiation patterns of the 2×4 arrays

Fig. 4 compares the measured normalized radiation patterns of the arrays. The 3-dB beamwidths in the E (y - z)- and H (x - z)-planes are 48° and 18° , respectively. Furthermore, the cross-polarization levels of less than -25 dB are observed in both the E- and H-planes. The achieved gain across the operating bandwidth reaches up to 9.5-11.3 dBi.

4. Conclusion

The transverse aperture etched onto the broad-wall of an SIW has been investigated for the bandwidth enhancement from 2.7% to 11.6% for a 10-dB return loss with unchanged radiation performance. The 2×4 aperture antenna array has been designed and measured at 60 GHz bands.

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