V-Band Circularly Polarized Wire-Bond Antenna Design

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***Abstract*—A V-band wide-coverage left-handed circularly polarized wire-bond antenna is presented. The proposed antenna mainly comprises of four wire-bonds surrounded a series-type power divider network to achieve circularly polarized radiation. In the talk, the design principle of wire-bonds with wide-coverage characteristics is presented. Also, the design method of power divider is included. The antenna has been fabricated with IPD process and measured. The simulation and measurement regarding antenna reflection coefficient, radiation pattern, peak gain, and axial ratio are conducted for design validation. The measured results show that the antenna can operate in V-band and the impedance bandwidth with $|S_{11}|$ less than -10 dB is from 51 GHz to 67 GHz or more (> 28%). The measured maximum gain is -1.0 dBi at 60 GHz with beamwidth of about 180 degree. In addition, the measured axial ratio is less than 3 dB in from 55 to 65 GHz.**

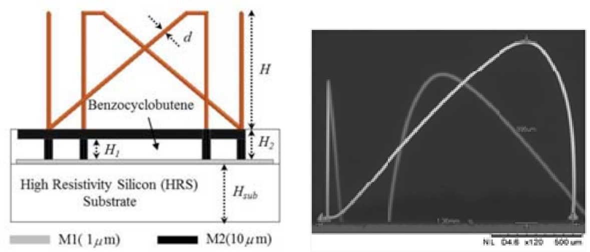
Keywords—circular polarization; millimeter-wave antenna; wire-bond structure

I. Introduction

In recent years, millimeter-wave (mmW) wireless systems have been developed for high data-rate, wide-bandwidth, and short-range wireless applications to meet the growing demand of high quality communication [1-2]. The idea of integrating antenna with RF front-end active circuits in chip or package level to miniaturize the size and the trace loss of system circuits becomes available in mmW wireless systems. However, implementing antenna in CMOS-based process has been proved to gain poor antenna efficiency because of lossy silicon substrate [3-4]. Even for providing high security of mmW wireless communications, circularly polarized system was also required in the system specification.

A wire-bond is possible to be used as an antenna at mmW frequency range and has been proposed to improve antenna gain and efficiency [5]. Because the antenna structure of wire-bond is away from the silicon substrate, it would alleviate the phenomenon of most energy confined in the silicon substrate and be easy to radiate in free space. Quadrifilar helix antennas (QHAs) are quite suitable to be equipped for circularly polarized applications with some attractive features as compact structure, cardioid-shaped radiation pattern and high front-to-back ratio [6].

In the talk, a V-band wide-coverage circularly polarized antenna design using bond-wire structures is presented. The proposed design, which is implemented with IPD process, consisting of a 1-to-4 series-type microstrip power divider of ring shape and four radiators which are implemented with bond wires. The power divider provides excitations with equal amplitude and 90-degree phase difference to radiators. The bond wires are deployed along the edges of the ground plane, to obtain wide-coverage radiation patterns. The performance of the proposed antenna is validated by full-wave simulation and measurements.



(a) (b)

Fig. 1. (a) The configuration and (b) microphotograph of proposed V-band circularly polarized wire-bond antenna.

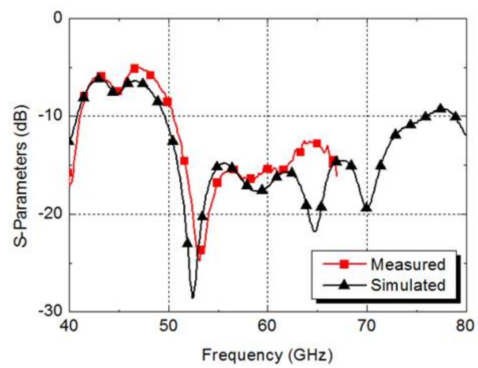


Fig. 2. The simulated and measured reflection coefficients of the proposed antenna in Fig. 1.

II. Antenna Design

The configuration of the proposed circularly polarized wire-bond antenna is shown in Fig. 1. It consists of a 1-to-4 power divider network with 90 degree phase difference fabricated on IPD process and four wire-bonds antenna array system. It is fed by a microstrip line embedded in 18-μm thick dielectric material with ε_r = 2.65. The width and thickness of the microstrip signal trace are 10 μm and the thickness between the signal and the ground plane is 5 μm . Considering its silicon substrate dielectric constant of 11.9, which is greater

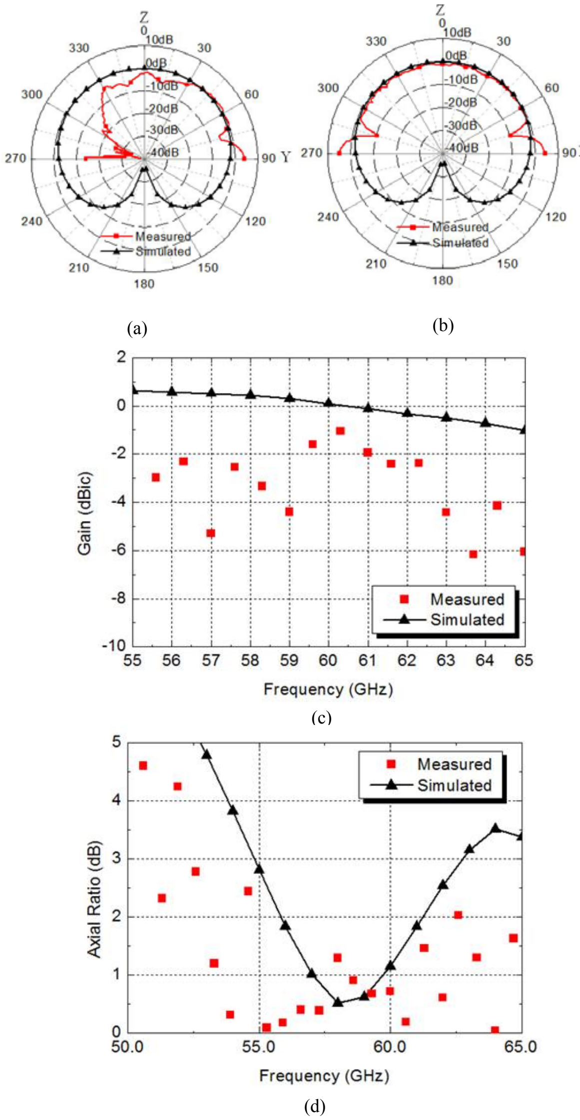


Fig. 3. The simulated and measured results: (a) y-z plane and (b) x-z plane radiation patterns at 60 GHz, (c) peak gain, and (d) axial ratio.

than 60 GHz equivalent length of $\lambda/4$ transmission line, easily lead to dielectric resonator mode, the thickness H_{sub} of silicon substrate IPD must be thinned to 200~300 μm to avoid excessive resonance interference happened on 60 GHz band and then lead to reduction of antenna gain. The effectively length of the wire-bond is $\lambda/2$ and its end is shorted to ground plane. Due to image theory, we expect this structure to have similar characteristics to a full loop antenna of circumference λ . The resonant frequency of the antenna is mainly controlled by H and L . The antenna was simulated in Ansoft HFSS and the parameters were designed for center frequency at 60 GHz: L_1=1400µm, L_2=450 µm, and H= 950 µm. The simulated peak gain is 2.6 dBi and radiation efficiency is 97%.

III. Measurement Results

Fig. 2 shows the simulated and measured reflection coefficients of the proposed antenna. The coefficients are measured by using Agilent network analyzer model E8361C with 4-port measurement capabilities. The simulated and measured results are in good agreement. The measured bandwidths are 7 GHz (57-64 GHz).

Fig. 3(a) and 3(b) shows the simulated and measured radiation patterns. The pattern measurements are conducted in an anechoic chamber and calibrated with standard gain horns. In the fig. 3(a), it is found that the antenna radiation is affected by the presence of the probe station. Nevertheless, the comparison is satisfactory. Fig. 3(c) shows the simulated and measured peak gains. The measured peak gain and beamwidth at 60 GHz are -1 dBi and more than 180 degree, respectively. Fig. 3(d) shows the simulated and measured axial ratios. The 3-dB AR bandwidth is from 55 GHz to 65 GHz.

IV. Conclusions

In the talk a novel design of a circularly polarized antenna operating in the unlicensed V-band fabricated by using IPD process and bonding wire technology is presented. The size of the fabricated antenna is 2.4 x 2.4 mm^2 . The use of wire-bonds surrounding structure with a series-type power divider network successfully achieved circularly polarized characteristics. The proposed bond-wire antenna has been validated by measurements, and satisfactory performance is obtained. The antenna is well suited for low-cost, compact, and high performance system-in-package mmW radio front ends.

References

[1] J.-L. Kuo, Y.-F. Lu, T.-Y. Huang. Y.-L. Chang, Y.-K. Hsieh, P.-J. Peng, I-C. Chang, T.-C. Tsai, K.-Y. Kao, W.-Y. Hsiung, J. Wang, Y.-A. Hsu, K.-Y. Lin, H.-C. Lu, Y.-C. Lin, L.-H. Lu, T.-W. Huang, R.-B. Wu, and H. Wang, "60-GHz Four-Element Phased-Array Transmit/Receive System-in-Package Using Phase Compensation Techniques in 65-nm Flip-Chip CMOS Process," *IEEE Trans. Microw. Theory Tech.*, vol. 60, no. 3, pp. 743–756, Mar. 2012.

[2] R. Daniels and R. Heath, "60 GHz wireless communications: emerging requirements and design recommendations," *IEEE Veh. Technol. Mag*., vol. 2, no. 3, pp. 41-50, Sept. 2007

[3] S.-S. Hsu, K.-C. Wei, C.-Y. Hsu, and H.-R. Chuang, "A 60-GHz millimeter-wave CPW-fed Yagi antenna fabricated by using 0.18um CMOS technology," *IEEE Electron Devices Lett.*, vol. 29, no. 6, pp. 625-627, June 2008.

[4] C.-C. Lin, S.-S. Hsu, C.-Y. Hsu, and H.-R. Chuang, "A 60-GHz millimeter-wave CMOS RFIC-on-chip triangular monopole antenna for WPAN applications," *IEEE Antennas and Propagation Society International Symposium, 2007*, pp. 2522-2525, June 2007.

[5] R Willmot, Dowon Kim, and D Peroulis, "A Yagi–Uda Array of High-Efficiency Wire-Bond Antennas for On-Chip Radio Applications," *IEEE Trans. Microw. Theory Tech*., vol. 57, no. 2, pp. 3315–3321, 2009.

[6] Q.-X. Chu, W. Lin, W.-X. Lin, and Z.-K. Pan, "Assembled Dual-Band Broadband Quadrifilar Helix Antennas With Compact Power Divider Networks for CNSS Application," *IEEE Trans. Antennas and Propagation,* vol. 61, no. 2, pp. 516-523, Feb. 2013.