300 GHz One-Sided Directional Slot Array Antenna on Indium Phosphide Substrate

Haruichi Kanaya[1], Tomoki Oda, Naoto Iizasa, and Kazutoshi Kato
Department of Electronics, Kyushu University, Fukuoka 819-0395, Japan
[1]kanaya@ed.kyushu-u.ac.jp

***Abstract* – This paper presents a novel design of 300 GHz band 1 x 4 one-sided directional slot dipole array antenna fed by coplanar waveguide (CPW) on indium phosphide (InP). The proposed antenna has four antenna elements and branched CPW structure to achieve a high antenna gain and a sharp beam. We fabricated and measured the array antenna. In the EM simulation, forward directional peak gain is 7.35 dBi. The measured reflection coefficient is agreed with the simulation results.**

***Index Terms* — Terahertz, array antenna, slot antenna, one-sided directional radiation, wireless communications**

I. Introduction

Recently, research of terahertz (THz) waves at frequencies has attracted much attention, since THz waves are suited to such novel applications as spectroscopic sensing, non-destructive imaging, and ultra-broadband wireless communications [1]. In basic THz broadband wireless communications, an optical signal was generated by two-mode beating using two lasers. Then, uni-traveling-carrier photodiode (UTC-PD) based on indium phosphide (InP) substrate converted the optical beat signal into sub-mm-waves by photomixing, and sub-mm-waves are radiated through the antenna [2].

In this system, 300 GHz-band communications will promise a data rate of 100 Gbit/s and there are a lot of researches about the high gain antennas for 300 GHz band. Wave guide array antenna [3] has a high gain and high directivity, however, antenna size is too large and it is difficult to fabrication. Tapered slot antenna [4] has a high gain, however antenna size is still large and large connection loss from the wire bonding. Bow tie antenna [5] has a planar structure and it is realized on InP substrate, however antenna gain is low and unwanted backward radiation is generated. Slot dipole antenna with floating metal layer is another type of the high gain and one-sided directional planar antenna [6 - 8], and it is easy to realize an array structure. In our previous report, high gain 4 x 4 slot dipole antenna array in the 5GHz band was developed [9].

In this paper, we present a novel design of a 300 GHz-band 1 x 4 array antenna using four one-sided directional slot dipole antenna elements fed by branched coplanar waveguide (CPW) [10]. We designed and simulated this antenna by electromagnetic field simulator (HFSS, Ansys). Moreover, we fabricated the array antenna on InP substrate and measured the frequency characteristics.

II. Design of Array Antenna

Fig. 1 shows the layout of the top and side view of a 1 x 4 slot dipole array antenna. The proposed antenna is designed on an InP substrate. InP substrate was etched by using deep inductively coupled plasma reactive ion etching, and placed on the floating metal layer (Au, thickness = 1.0 μm) and polyimide dielectric layer (ε_r = 3). Antenna is designed on the top metal layer (Au, thickness = 1.0 μm). In the figure slot width of the antenna element is 20 μm. This antenna has a floating metal layer on the bottom, and by optimizing the length of floating metal layer, one-sided directional radiation can be realized. For measurement, GND-Ggnal-GND pads are attached. The effect of the of the InP substrate is reduced by this floating metal layer

In order to obtain a high antenna gain to z-axis direction, the RF power is injected to each antenna element with the same phase through the branched CPW feed line. The total antenna size is 1,217 μm x 2,550 μm including in dicing clearance.

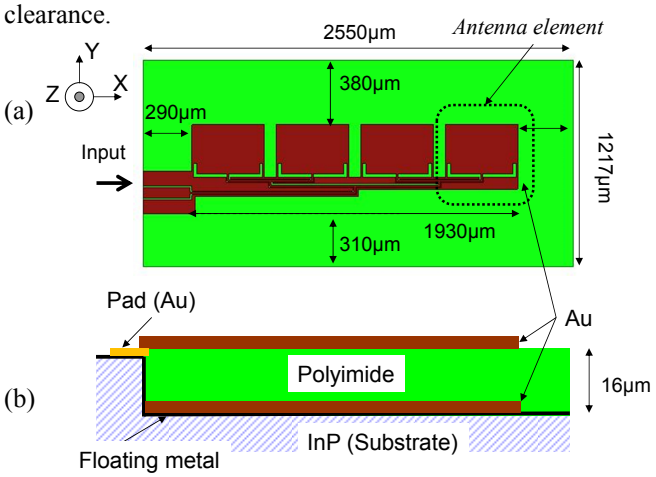
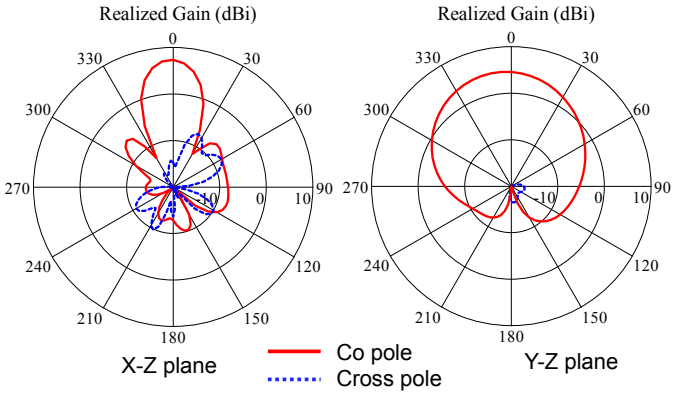


Fig. 1. Layout of the slot array antenna. Top view (a) and side view (b).

Fig. 2 shows the simulated radiation patterns of x-z (a) and y-z planes (b) at 300 GHz, respectively. In this simulation, all mutual couplings are included. The sharp radiation patterns

were obtained in y-z plane because of 4-array structure. In x-z plane, since antenna is not arrayed, this radiation pattern shows that of the 1-antenna element. At 300 GHz, simulated realized gain in +z direction is 7.35 dBi, which is more than 5 dB larger than conventional dipole antenna.



(a) x-z plane (b) y-z plane

Fig. 2. Simulated radiation patterns of the x-z (a) and y-z planes (b) at 300 GHz.

III. Measurement Results

Fig. 3 shows the photograph of the fabricated antenna. During the fabrication, many cracks occurred on the top of the polyimide. RF signal is fed to CPW on the top metal layer by GSG probe (I325-T-GSG-75-BT, Cascade Microtech). From Fig.3, because the bottom floating metal layer suppresses the radiation of the downward direction (-z direction), the radiation characteristics do not change when the proposed antenna was placed on the measured stage. Fig. 4 shows the measured results of S_{11}. Our proposed antenna has center frequency =282.0 GHz and S_{11} = -35.4 dB.

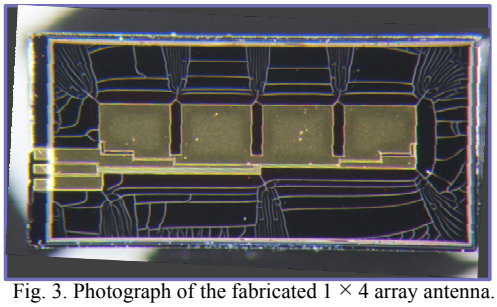


Fig. 3. Photograph of the fabricated 1 × 4 array antenna.
(Size: 2,550 μm x 1,217 μm x 18 μm, with dicing clearance.)

IV. Conclusion

This paper presents 1 x 4 slot dipole array antenna fed by branched CPW on InP substrate for 300 GHz band high speed data transmission application. Design of the antenna element is based on the one-sided directional slot antenna with floating metal layer. The size of the proposed antenna is 2,550 μm x 1,217 μm x 18 μm. This antenna has 7.35 dBi antenna gain and 20.17 dB front-to-back (F/B) ratio at 300 GHz in simulation. Our proposed antenna is suitable for implemented the InP based photo electronics device.

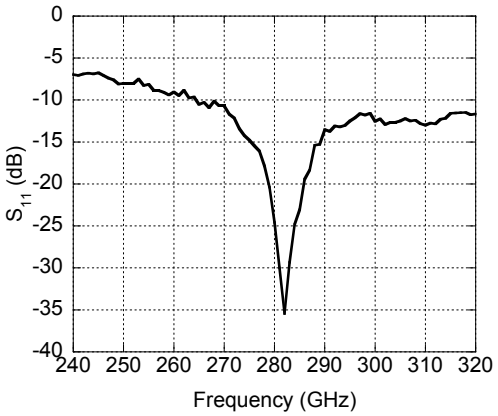


Fig. 4. Measured result of S-parameter.

Acknowledgment

The authors would like to express thanks to Prof. Tadao Nagatsuma, Osaka University, and Prof. Minoru Fujishima and Dr. Kyoya Takano, Hiroshima University for their help and support. This work was partly supported by a Strategic Information and Communications R&D Promotion Programme (SCOPE), from the Ministry ofInternal Affairs and Communications, Japan, and a JSPS Grant-in-Aid for KAKENHI (Kiban-C) and CREST, Japan.

References

[1] T. Nagatsumal, K. Kato, “Photonically-assisted 300-GHz Wireless Link for Real-time 100-Gbit/s Transmission”, Digest, 2014 IEEE MTT-S International Microwave Symposium, 2014, pp. 1-4.

[2] H. Ito, Y. Muramoto, H. Yamamoto, T. Ishibashi, “Matching-Circuit-Integrated InGaAsP Schottky Barrier Diode for Zero-Biased Operation in the Sub-Millimeter-Wave Range”, Japanese Journal of Applied Physics 51 ,2012, 114101.

[3] A. Boryssenko, K. Vanhille, “300 GHz Microfabricated Waveguide Slotted Arrays”, Proc. 39th International Conference on Infrared, Millimeter, and Terahertz waves, 2014, pp. 14-19.

[4] M. Inoue, M. Hodono, S. Horiguchi, M. Fujita, T. Nagatsuma, “Ultra-broadband Tapered Slot Terahertz Antennas on Thin Polymeric Substrate”, Proc. International Symposium on Antennas & Propagation, 2013, pp. 633-636.

[5] R. Yano, H. Gotoh, Y. Hirayama, “Terahertz wave detection performance of photoconductive antennas: Role of antenna structure and gate pulse intensity”, J. Applied Physics, 97, 2005, 103103.

[6] H. Kanaya, Y, Koga, G. Urakawa, K. Yoshida, “Design of HTS Coplanar Waveguide Matching Circuit for Low Noise CMOS-HTS Receiver”, IEEE Trans. on Applied Superconductivity, Vol. 13, No. 2, 2003, pp. 1031-1034 .

[7] H. Kanaya, R. Nabeshima, R. Pokharel, K. Yoshida, M. Tsujii, R. Iino, “Development of an Electrically Small One-Sided Directional Antenna with Matching Circuit,” IEEE Radio and Wireless Symposium Proceedings, 2008, pp. 739-742.

[8] H. Kanaya, S. Tsukamoto, T. Hirabaru, D. Kanemoto, R. K. Pokharel, K. Yoshida, “Energy Harvesting Circuit on a One-Sided Directional Flexible Antenna”, IEEE Microwave and Wireless Components Letters, Vol. 23, Issue 3, 2013, pp. 164-166.

[9] N. Iizasa, K. Yoshitomi, R. Pokharel, H. Kanaya, “High Gain 4 x 4 Slot Dipole Antenna Array in the 5GHz Band”, Proc. Asia-Pacific Conference on Antennas and Propagation, 2014, pp. 197-200.

[10] H. Kanaya, T. Shinto, K. Yoshida, T. uchiyama, Z. Wang, “Miniaturized HTS Coplanar Waveguide Bandpass Filters with Highly Packed Meanderlines”, IEEE Trans. on Applied Superconductivity, vol. 11, No. 1, 2001,pp. 481-484.