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A Triangular Loop Antenna Mounted Adjacent to a Lossy Semiconductor Substrate for Millimeter-Wave WPAN

#Yukako Tsutsumi [1], Masaki Nishio [1], Shuichi Sekine [1], Hiroki Shoki [1], Tasuku Morooka [2]
[1] Corporate Research & Development Center, Toshiba Corp.
[2] Toshiba Research Consulting Corp.
1, Komukai-Toshiba-cho, Saiwai-ku, Kawasaki 212-8582, Japan
E-mail: yukako.tsutsumi@toshiba.co.jp

1. Introduction

Millimeter-wave wireless communication is expected to be used for Wireless Personal Area Network (WPAN) for which a bit rate of 1Gbps or more is needed [1].

In a millimeter-wave band, it is possible to build an antenna into the module by such means as an on-chip antenna [2], [3] or a package antenna [4], because the small antenna can be composed. It is well known that the semiconductor substrate degrades an antenna gain by its conductor loss. Therefore, several approaches have been proposed to improve the radiation efficiency of antennas; for example, methods of using high resistance substrates [2], [5], methods of forming cavities under antennas [6]-[8], and a method of using a superstrate structure over an antenna substrate [8].

Our goal is the development of an antenna suited to a WPAN terminal. Since a small, low-cost antenna with high radiation efficiency and a high gain in a wide-angle range is required for WPAN, the beam scan becomes unnecessary. In this paper, we propose a novel triangular loop antenna with a simple structure that has a feed point on a semiconductor substrate. The validity of this antenna is shown by simulation results and the measurement results of a scale model.

2. Antenna Structure

Figure 1 shows the configuration of the proposed antenna. The figure of the triangular antenna is a solid loop shape. It has a feed point in the vicinity of the edge of a semiconductor substrate, which is mounted on a dielectric substrate, and the feed point and the vicinity of both edges of a wide metallic plate on the dielectric substrate are connected with metallic wire elements. The electrical length of the metallic plate is about half wavelength and the total length of the loop is about one wavelength. The thickness of the semiconductor substrate is about 300 um. It consists of lossy semiconductor media with a thin dielectric layer formed on its surface. Although this antenna is mounted adjacent to the lossy silicon substrate, there is little deterioration in efficiency due to the influence of a loss medium because the elements of the proposed antenna are apart from the surface of the semiconductor substrate.

3. Simulation Results and Measurement Results of the Scale Model

The antenna model including the substrates shown in Fig.1 was used for the simulation. The simulation was done by using MW-Studio. At 60GHz band the size and the medium relative permittivity of dielectric substrate were 4000um×4000um and ε_r=4.0, respectively, and the size and the medium relative permittivity of the semiconductor substrate were 2000um×2000um and ε_r=11.7, respectively.

Figure 2 shows the dependence of the resistivity ρ of the semiconductor substrate on the VSWR of the proposed antenna. This graph is normalized by the differential impedance of 100Ω.

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The input impedance becomes small as the resistivity becomes small, and the VSWR is improved. This is because the loss absorbed to the semiconductor substrate increases as the resistivity becomes small. Figure 3 shows the dependence of the resistivity on the radiation efficiency and antenna gain. For the purpose of comparison, the simulated results of an on-chip dipole antenna model are also shown in Fig.3. The on-chip dipole antenna model including the substrates is shown in Fig.4. The radiation efficiency and antenna gain of the on-chip dipole antenna decrease linearly as the resistivity becomes small. This result shows that the on-chip dipole antenna is susceptible to the loss of the semiconductor substrate. The radiation efficiency and antenna gain of the proposed antenna are 5-8dB higher than those of the on-chip antenna and even if the resistivity becomes small, their deterioration is slight.

The simulation and measurement results at 2GHz band were obtained by use of a scale model. A photograph of the scale model including the proposed antenna for experiment is shown in Fig.5. At 2GHz band each size was enlarged by 30 times and the medium constants were kept the same as for the model of 60GHz band in the high lossy case of ρ=1Ω-cm. The simulated and measured VSWR results of the scale model are shown in Fig.6. The measured VSWR is reasonable but the value is slightly lower compared with the simulated results. This is attributable to differences of the medium constants of the semiconductor and dielectric substrates used for the calculation and measurement. Figure 7 shows the radiation pattern of the antenna including substrates. The radiation pattern of the model of 60GHz band in the case of ρ=1Ω-cm is also shown in Fig.7. These are patterns at the frequencies of 2.28GHz, 2.26GHz and 68.0GHz, at which VSWRs are the best, respectively. The E_θ components of the simulated antenna gains are very small. The simulated and measured results at 2GHz band are in good agreement though the measurement antenna gains are deteriorated by about 1dB due to differences of the permittivity of the substrates. The simulated antenna gain at 68GHz is about 1dB lower than the simulated one at 2.28GHz. At θ=90[deg], ϕ=270[deg], the simulated antenna gain at 68GHz, the simulated and measured antenna gains at 2GHz band are -0.4dBi, 2.0dBi and 0.9dBi, respectively. And high gains are kept over the wide range of the elevation of about 90 degrees.

4. Conclusion

A novel triangular loop antenna mounted adjacent to a lossy semiconductor substrate that has efficient and wide-angle radiation characteristics was presented. The validity of this antenna at 60GHz band was shown by the simulation and measurement results of the scale model. It was shown that an antenna gain of -0.4dBi or more is obtained over a wide range of elevation of 90 degrees forward of the antenna in spite of the proximity of the antenna and the lossy semiconductor substrate at 60GHz band. The improvement of the VSWR characteristic is a subject for future work.

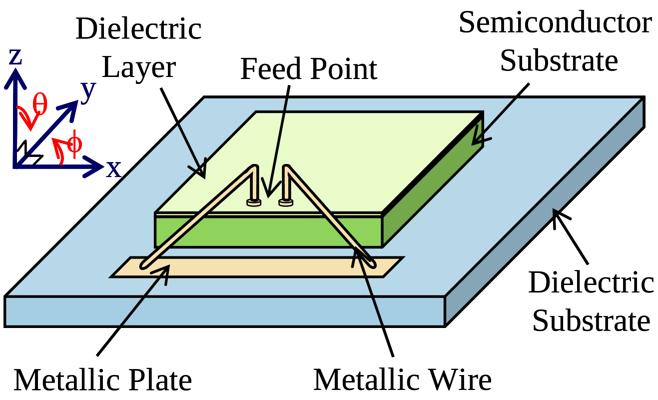

Fig.1: Geometry of the proposed antenna including the substrates

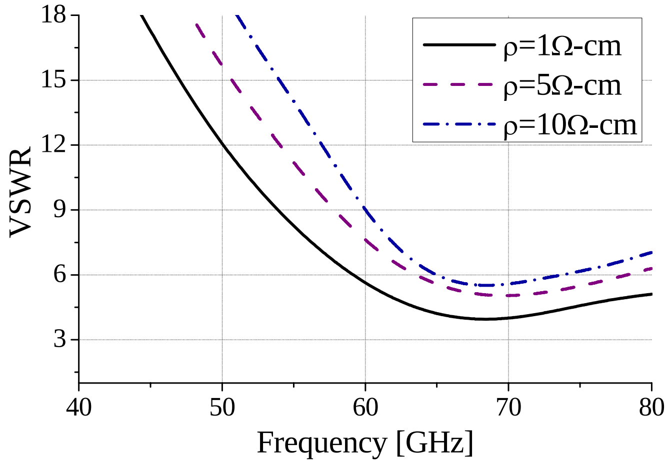

Fig.2: VSWR of the proposed antenna at feed point
(Z_0=100Ω, ρ: parameter)

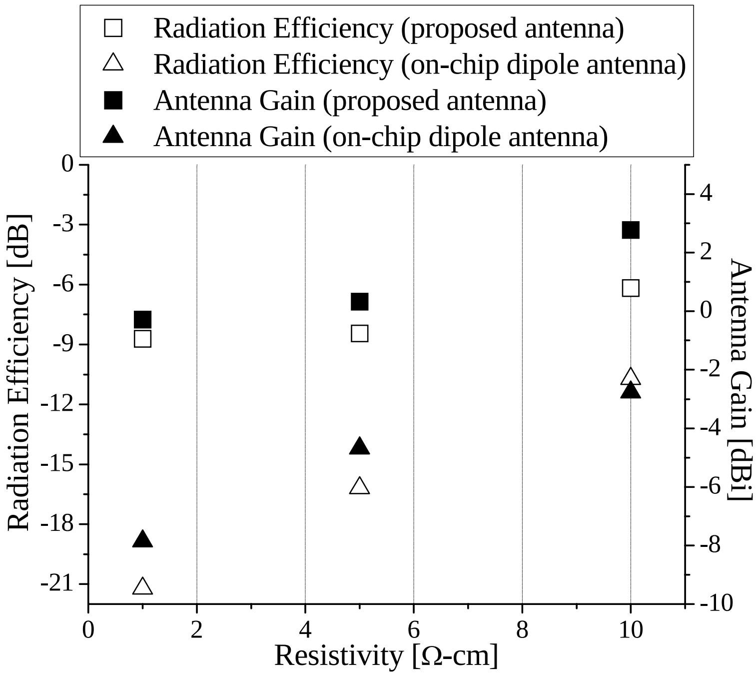

Fig.3: Dependence of the resistivity
on the radiation efficiency and antenna gain at 60 GHz band

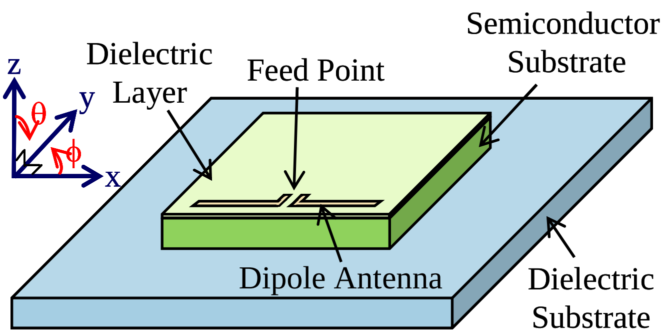

Fig.4: Geometry of the on-chip dipole antenna model including the substrates

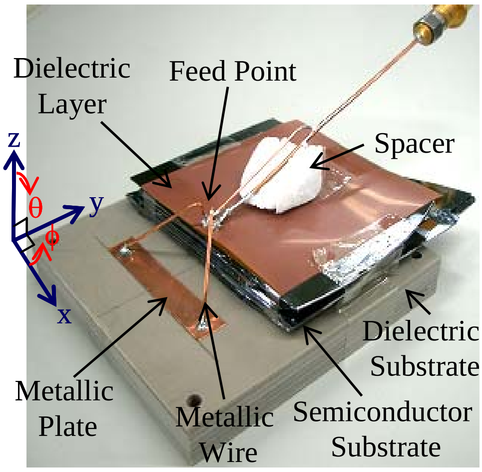

Fig.5: Photograph of the scale model for experiment

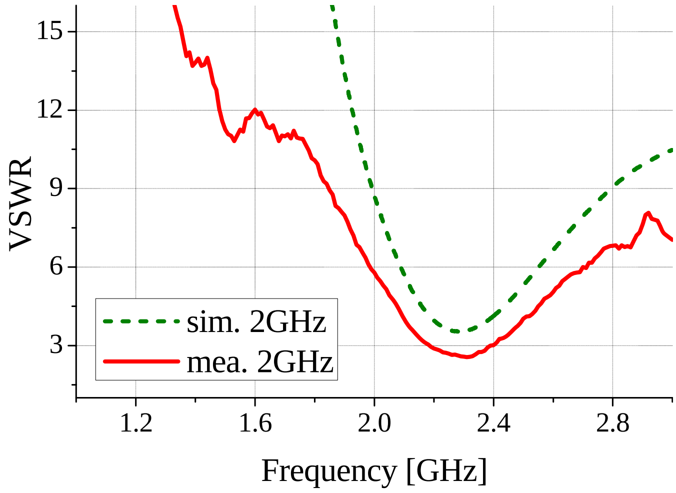

Fig.6: VSWR of the proposed antenna at feed point (2GHz band, Z_0=100Ω)

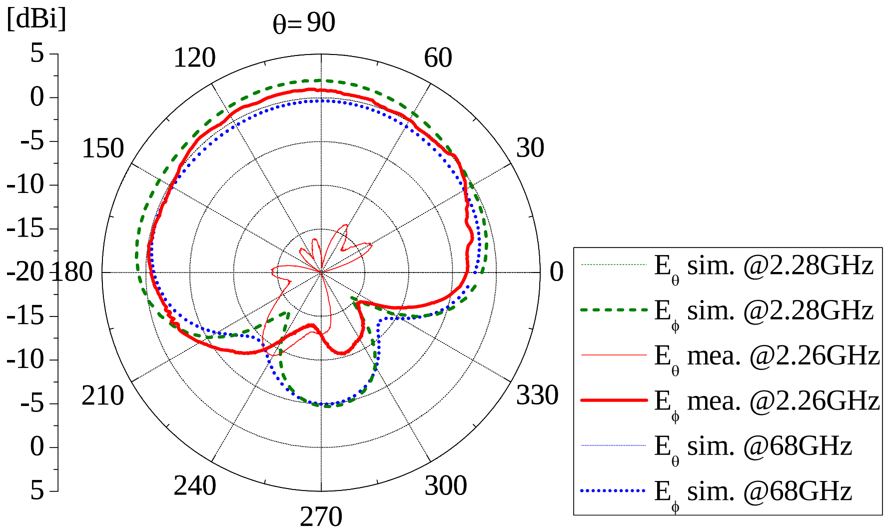

Fig.7: Radiation pattern (ϕ=270[deg], yz-plane)

References

[1] H. Ogawa et al., "Millimeter wave wireless personal area network (WPAN) and its standardization activity within IEEE802.15", Proc. ICMMT 2004, pp. P/14-P/17, Aug, 2004.
[2] N. Segura et al., "On-wafer radiation pattern measurements of integrated antennas on standard BiCMOS and glass processes for 40-80GHz applications", Proc. ICMTS 2005, pp. 107-111, April, 2005.
[3] M. Pons et al., "Study of on-chip integrated antennas using standard silicon technology for short distance communications", EUWC 2005, pp. 253-256, Oct. 2005.
[4] T. Seki et al., "Millimeter-wave high-efficiency multilayer parasitic microstrip antenna array on teflon substrate", IEEE trans. MTT, vol. 53, no. 6, pp. 2101-2106, Jun. 2005.
[5] K. T. Chan et al., "Integrated antennas on Si, proton-implanted Si and Si-on-quartz", IEDM, pp. 40.6.1-40.6.4, Dec. 2001.
[6] M. Abdel-Aziz et al., "Microstrip patch antenna using silicon micromachining technology", NRSC 2003, pp. B16 - 1-8, Mar. 2003.
[7] Y. Koga et al., "Cavity-backed MEMS patch antennas on double-layer silicon wafers", APS 2006, pp. 3935-3938, Jul. 2006.
[8] J. Grzyb et al., "Wideband cavity-backed folded dipole superstrate antenna for 60 GHz applications", APS 2006, pp. 3939-3942, Jul. 2006.