Proceedings of ISAP 2014, Kaohsiung, Taiwan, Dec. 2-5, 2014

Millimeter-wave Broadband Mode-Transition between Grounded Coplanar Waveguide and Post-wall Waveguide

Ryohei Hosono, Yusuke Uemichi, Xu Han, Ning Guan, and Yusuke Nakatani
Fujikura Ltd.
1440, Mutsuzaki, Sakura, Chiba, JAPAN

***Abstract* - In this paper, a broadband mode-transition between grounded coplanar waveguide (GCPW) and post-wall waveguide (PWW) is proposed. The transition is composed of GCPW, microstrip line (MSL) and PWW. The transition is fabricated on liquid crystal polymer (LCP) substrate due to its low dielectricity and availability of roll-to-roll process for fabrication of devices with cost reduction. The GCPW GSG pad has two through-holes at longitudinal direction and a rectangular slot are added in each pattern of ground pads. Broadband impedance matching is obtained by these structures thanks to an addition of lumped inductance and capacitance to the mode-transition. In the mode-transition between MSL to PWW, a shape of microstirp line is tapered and dimension is optimized for broadband operation. A 24% impedance bandwidth for $|S_{11}|$ less than -15 dB is achieved in measurement of fabricated mode-transition. Loss of GCPW GSG pad and MSL-PWW transition with 0.120 dB and 0.276 dB at 60 GHz are evaluated from measured results. This mode-transition is one of candidate for usage of low loss antenna-in-package with substrate at higher frequency band.**

***Index Terms* — Broadband mode-transition, GCPW GSG pad, LCP substrate, Lumped impedance matching, Antenna-in-package.**

I. INTRODUCTION

In recent years, large capacity and high-data-rate wireless communications are required and technologies such as small cell backhauling and HD transmission by mobile handset such as smartphone and tablet are developed. To satisfy the requirements, wider bandwidth is needed but it is limited in a microwave region (3 to 30 GHz). A millimeter-wave frequency band (30 to 300 GHz) is good candidate to realize the huge capacity and high speed communications. For example, there exists a large unlicensed bandwidth at 60 GHz band up to 9 GHz [1]-[2] and many kinds of technology related to 60 GHz band are now developed for rapid growth of market related to 60 GHz in the near future. Devices with broadband operation and low loss characteristics are required in many cases such as electrical packaging with IC.

In this paper, a broadband mode-transition between grounded coplanar waveguide (GCPW) and post-wall waveguide (PWW) on liquid crystal polymer (LCP) substrate is proposed. This mode-transition has a variety of application of not only a low cost electrical packaging with RFIC and antenna (antenna-in-package) such as slot antenna with PWW but also precise evaluation of characteristics of planar devices with GSG (Ground-Signal-Ground) pad. The LCP substrate is one of RF substrates and it has availability conventional fabrication technology of flexible printed circuit (FPC) such as roll-to-roll process which contributes to a cost reduction of devices with substrate. We believe that RF device with the LCP substrate is good candidate for 60 GHz application.

Some kinds of planar mode-transition structures at higher frequency band are proposed [3]-[5]. [3] provides a novel via-less CPW to microstrip line (MSL) mode-transition on silicon substrate which operates up to 40 GHz. There is a large difference in frequency characteristics of insertion and return loss among devices with several CPW length but losses are degraded immediately around 50 GHz. The CPW to MSL mode-transition is also applied operating at 60 GHz band in [4] but the shape of the GCPW pad is not refined well. A broadband via-less mode-transition between coplanar probe to microstrip is also proposed in [5]. The mode-transition has a return loss less than -14 dB from 50 to 67 GHz but an optimum taper transition from the CPW to the MSL and a back pad which makes an increase of size and must be fabricated precisely are needed. This mode-transition is designed to operate at wider 60 GHz band by the addition of two through holes and a slot to the GCPW ground pattern and the tapered MSL at the transition to a discontinuous part between the MSL and the PWW. The mode-transition is also designed compatible with compact shape. Additionally, losses of each part including that of the PWW per unit length which are not reported in [4] of transition are also evaluated for the design guideline of transmission line operating at millimeter wave band.

II. DESIGN OF MODE TRANSITION

The proposed mode-transition configuration is shown in Fig. 1. The ground pattern of the GCPW has rectangular shpae whose longitudinal direction is same as an axis of transmission line for compact design. A lumped impedance matching is obtained due to an addition of appropriate inductance and capacitance by adjusting dimensions of the vias and rectangular slot. LCP substrate with thickness of 0.175 mm is used and a relative permittivity of 2.9 and loss tangent of 0.003 are assumed.

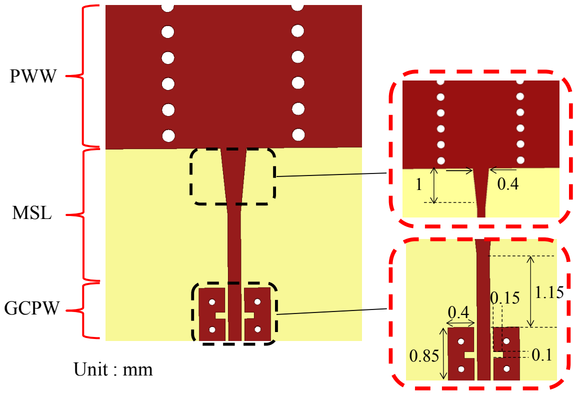

Fig. 1. Configuration of mode transition.

III. SIMULATED AND MEASURED RESULTS

To show the effect of broadband operation, measured insertion and return loss characteristics of mode-transition for several length of the PWW (4.8 mm and 9.6 mm). Return loss less than -15 dB from 52.7 GHz to 67 GHz is obtained and a dependency of transmission line length which is appeared in [3] is relatively small. Figure 3 shows measured loss of mode-transition from the GCPW to the PWW. The loss is calculated by de-embedding technique [6] from S-parameters of two PWWs of the length of 4.8 mm and 9.6 mm. Measured loss less than 0.5 dB from 53 to 67 GHz is obtained. The loss of mode-transition is enough to satisfy the requirement in millimeter wave application. Table I shows losses of each part of the mode-transition and the loss of the PWW per unit length (dB/mm) at 60 GHz which are also calculated from same de-embedding technique. The loss of the GCPW pad and loss of straight MSL are calculated with two kinds of the MSL with proposed GCPW pads. The loss of tapered MSL of 0.26 dB is estimated by subtracting losses of the GPCW and the MSL from insertion loss of whole loss of the mode-transition from the GCPW to the PWW. The insertion loss of the GCPW is around 0.1 dB and it is found that the loss of tapered MSL dominates in proposed mode-transition.

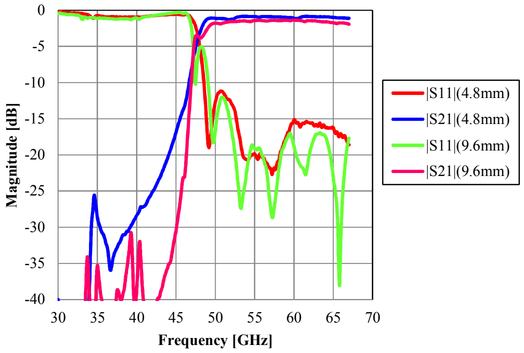

Fig. 2. Measured insertion and return loss of mode-transition for different length of PWW.

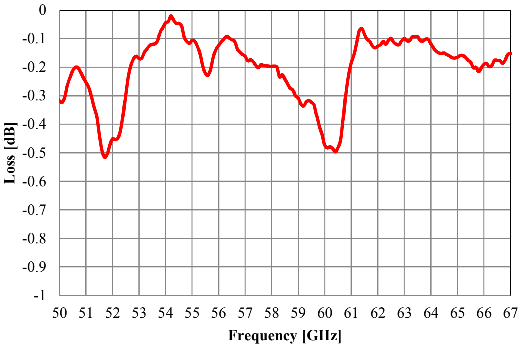

Fig. 3. Measured loss of mode-transition (GCPW-PWW).

TABLE I
Measured losses of mode-transition at 60 GHz.

Type of loss	Value
Loss of GCPW pad	0.120 dB
Loss of straight MSL (length=1.15 mm)	0.067 dB
Loss of mode transition (GCPW-PWW)	0.463 dB
Loss of tapered MSL (length=1 mm)	0.276 dB
Loss of PWW per mm	0.086 dB/mm

IV. CONCLUSION

In this paper, broadband mode-transition is designed and evaluated. Mode-transition is composed of GCPW with two vias and slot on ground pattern and straight and tapered MSL. Lumped impedance matching at around 60 GHz band is realized with loss of mode-transition less than 0.5 dB and loss of tapered MSL is predicted. This mode-transition is helpful for low loss millimeter wave packaging and evaluation of some passive or active millimeter wave devices with RF probe.

REFERENCES

[1] Status of Project IEEE 802.11ad-Very High Throughput in 60GHz, URL: http://www.ieee802.org/11/Reports/tgad_update.htm
[2] IEEE 802.15 WPAN Millimeter Wave Alternative PHY Task Group 3c (TG3c),URL: http://www.ieee802.org/15/pub/TG3c_contributions.html
[3] G. Zheng, J. Papapolymerou, M. M. Tentzeris, "Wideband Coplanar Waveguide RF Probe Pad to Microstrip Transitions Without Via Holes," IEEE Microwave and Wireless Components Lett., vol.13, no.12, pp.544-546, Dec. 2003.
[4] D. Zelenchuk and V. Fusco, “Low insertion loss substrate integrated waveguide quasi-elliptic filters for V-band wireless personal area network applications,” IET Microwaves, Antennas and Proagat., vol. 5, no. 8, pp. 921-927, June, 2011.
[5] Y. C. Lee and C. S. Park, "Vialess Coplanar Probe Pad-to-Microstrip Transitions for 60 GHz-band LTCC Applications," 36th European Microwave Conference, pp.1354-1357, Manchester , UK, Sept. 2006.
[6] A. M. Mangan, S. P. Voinigescu, M. T. Yang, and M. Tazlauanu, “De-embedding transmission line measurements for accurate modeling of IC designs,” IEEE Transactions on Electron Devices, vol. 53, no. 2, pp. 235-241, Feb. 2006.