Wideband low-profile Substrate-Integrated Waveguide-Based 60-GHz Magneto-Electric Dipole Antenna

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***Abstract*—This paper presents a Substrate-Integrated Waveguide-feed magneto-electric dipole antenna for millimeter-wave, particularly fifth generation (5G) applications. The proposed antenna has high gain, wide bandwidth, and low profile, so it is low cost and easy to be integrated. The antenna consists of an opening cavity formed by metalized vias, which encloses a single feed magneto-electric dipole antenna. The proposed antenna achieves a simulated impedance bandwidth of 54.8% covering 45.3 GHz to 79.5 GHz. the 3-dB gain bandwidth is 50.6%.the 3-dB z-direction gain bandwidth is 35.8%. The maximum boresight gain is up to 9.7 dBi.**

Keywords—low profile, wide bandwidth, Substrate-Integrated Waveguide, Magento Electric Dipole Antenna.

I. INTRODUCTION

In recent years, due to the rapid development of modern wireless communications, the old frequency band could not suffer the growing mega data. On July 14, 2016, the fifth generation (5G) wireless communication standard was unveiled when the US Federal Communications Commission's passed the Spectrum Frontiers vote. The document declares that a total of 3.85 GHz licensed spectrum is opened in 28, 37 and 39 GHz bands and a new unlicensed band from 64 to 71 GHz [1]. The new band of 64-71 GHz will extend the existing high-band unlicensed spectrum (57-64 GHz), which will double the amount of unlicensed spectrum to 14 GHz. As an essential component in the fifth generation (5G) wireless communication system, there are new requirements for the designs of millimeter-wave antennas to achieve a wide bandwidth of 22%.

In millimeter-wave, various unidirectional antennas have already been proposed which include: Yagi-Uda antenna, the horn antenna, and the dielectric rod antenna[2]-[4]. However, lighter weight and smaller size components are desirable in millimeter-wave. These designs have a high profile, large size, and high cost, and thus are not suitable for many applications. A novel wideband antenna is reported by Wong and Luk [5] in 2006, which is called the magneto-electric (ME) dipole antenna, which has wide bandwidth, stable gain, and low front-back radiation level.

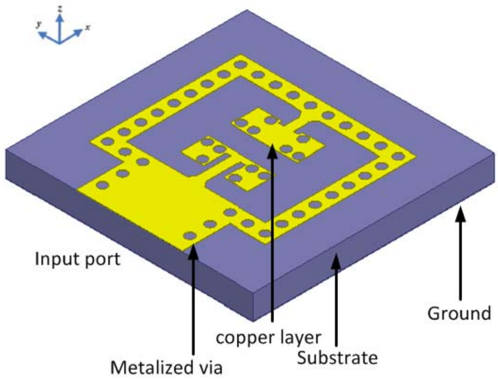

Fig.1 Geometry of the proposed antenna.

The integration of OFF-chip antennas to monolithic integrated circuits (ICs) is also a concern at mm-wave frequencies. Many IC designs rely on microstrip line feeding network, which suffers from high transmission loss, large back-lobe radiation, and low radiation efficiency[6]-[7]. Therefore, the antennas fed by substrate integrated waveguide (SIW) [8]-[9] are more attractive in such high-frequency band.

II. ANTENNA DESIGN

Fig.1 shows the geometry of the proposed antenna. The design of this antenna with a single-layer ROGERS 5880 laminate ($\varepsilon_r = 2.2$, tan $\delta = 0.0009$, and thickness h= 0.787 mm) was optimized. The antenna consists of an SIW feeding line, a half magneto-electric (ME) dipole structure, a half dummy ME dipole structure and a cavity of vias.

The ME dipole of this design consists of a patch antenna as E dipole and 6 vias as M dipole. The ME dipole is connected to the SIW feed by a copper line. A cavity of vias is for higher gain and better radiation pattern. The proposed antenna consists of a ground plane for enhancing the directivity.

III. SIMULATED RESULTS AND DISCUSSION

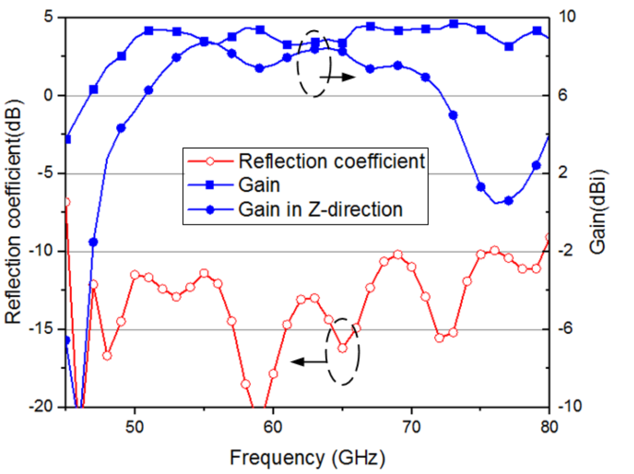

Fig.2 Simulated reflection coefficients, gain and gain in Z-direction of the proposed antenna

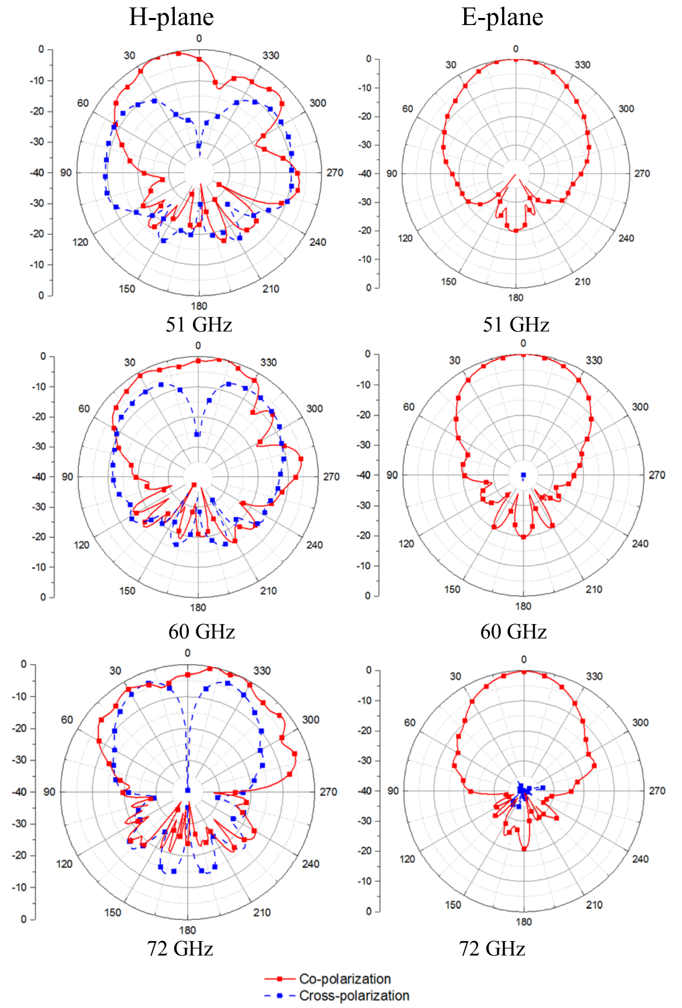

Fig.4 Simulated radiation patterns of the proposed antenna.

Fig. 2 shows the simulated reflection coefficient along with the gains in max-direction and Z-direction. The impedance bandwidth is from 45.5 GHz to 79.5 GHz, which is 54.8%, for $|S_{11}|$<-10dB. For 3 dB gain at z-direction, the bandwidth is 35.8% from 51GHz to 72 GHz, the maximum value of which is 8.7 dBi. Besides, the total 3-dB gain bandwidth is 50.6% from 47.5 GHz to 79.5 GHz, the maximum value of which is 9.7 dBi. Fig. 3 shows the simulated radiation patterns at 51 GHz, 60 GHz, and 72 GHz. Because of the unbalance of the antenna, the cross-polarization level is high at H-plane, the maximum value of which is 5 dB. For E-plane, because it is a balanced plane, the main lobe is sharp and the cross-polarization level is low.

IV. Conclusion

A Substrate-Integrated Waveguide-feed magneto-electric dipole antenna for millimeter-wave has been presented. It features a wide operating bandwidth of 35.8% from 51 GHz to 72 GHz, which can cover 60 GHz unlicensed frequency band, and a maximum gain of 8.7 dBi. The simulated radiation patterns exhibit low back radiation level. The antenna is low profile and single layer, which is attractive in millimeter-wave produce design.

References

[1] Fact Sheet: Spectrum Frontiers Rules Identify, Open up Vast Amounts of New High-Band Spectrum for Next Generation (5G) Wireless Broadband. Accessed on Jul. 14, 2016. [Online]. Available: https://apps.fcc.gov/edocs_public/attachmatch/DOC-340310A1.pdf and https://www.fcc.gov/document/rules-facilitate-next-generation-wirelesstechnologies

[2] A. R. Mallahzadeh and S. Esfandiarpour, “Wideband H-plane horn antenna based on ridge substrate integrated waveguide (RSIW),” IEEE Antennas Wireless Propag. Lett., vol. 11, pp. 85–88, 2012.

[3] S. Jafarlou, M. Bakri-Kassem, M. Fakharzadeh, Z. Sotoodeh, and S. Safavi-Naeini, “A wideband CPW-fed planar dielectric tapered antenna with parasitic elements for 60-GHz integrated application,” IEEE Trans. Antennas Propag., vol. 62, no. 12, pp. 6010–6018, Dec. 2014.

[4] N. Ghassemi and K. Wu, “Planar dielectric rod antenna for gigabyte chip-to-chip communication,” IEEE Trans. Antennas Propag., vol. 60, no. 10, pp. 4924–4928, Oct. 2012

[5] K. M. Luk and H. Wong, “A new wideband unidirectional antenna element,”Int. J. Microw. Opt. Technol., vol. 1, no. 1, pp. 35–44, Jun.2006.

[6] Mingjian Li ; Kwai-Man Luk,’ Low-Cost Wideband Microstrip Antenna Array for 60-GHz Applications’ IEEE Trans. Antennas Propag., vol. 62, no. 6, pp. 3012–3018, Mar. 2014

[7] Ali Attaran ; Rashid Rashidzadeh ; Ammar Kouki:’ 60 GHz Low Phase Error Rotman Lens Combined With Wideband Microstrip Antenna Array Using LTCC Technology’, IEEE Trans. Antennas Propag., vol. 64, no. 12, pp. 5172–5180, Oct. 2016

[8] Dia’aaldin J. Bisharat, Shaowei Liao and Quan Xue.’ High Gain and Low Cost Differentially Fed Circularly Polarized Planar Aperture Antenna for Broadband Millimeter-Wave Applications’ IEEE Trans. Antennas Propag., vol. 64, no. 1, pp. 33–42, Jan. 2016

[9] F. Xu and K. Wu, “Guided-wave and leakage characteristic of substrate integrated waveguide,” IEEE Trans.Microw. Theory Techn., vol. 53, no. 1,pp. 66–73, Jan. 2005.