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SIW slot antenna for E-band communications

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Abstract—The paper proposes novel substrate integrated waveguide (SIW) slot antenna for E-band communications. The antenna is designed at a two-layer low temperature co-fired ceramic (LTCC) substrate in 71-76 GHz frequency band. The proposed antenna demonstrates a gain better than 11.3 dBi and efficiency of 85% and can be used as a standalone antenna or as an element of a larger array.

Keywords—SIW, LTCC; slot antenna, E-band communications

I. INTRODUCTION

The large spectrum available has recently attracted attention to E-band backhaul systems [1]. Both 71-76 GHz and 81-86 GHz band allow 10 GHz of bandwidth for increased data rates in order to satisfy the demand on multi-gigabit wireless applications for mobile network infrastructure.

The wideband, high-gain antennas are required for these millimeter-wave applications. Due to quite stringent requirements the antenna solutions developed include horn arrays [2], lenses [3], and reflector antennas [4]. Those are bulky and can hardly be employed for compact mobile terminals. Waveguide slot antenna arrays [5] have recently been shown to provide good alternative to the bulky 3D structures. Still the manufacturing process can be precluding them from mass-market.

An alternative to the hollow waveguide is present in SIW waveguide antennas that have been successfully applied at mm-wave frequencies [6]. The SIW slot arrays with multilayer corporate feed have been demonstrating wideband and high-gain performance. However, the use of subsequent interlayer slot couplers can lead to a complicated design and increases cost. In this paper, we propose a dielectric loaded SIW slot antenna that employs only two dielectric layers and designed on LTCC substrate. The antenna can be subsequently used as an antenna element in larger arrays or as a standalone component.

II. DESIGN

A. Antenna description

A layer structure of the LTCC antenna is shown in Fig. 1. The dielectric properties of the LTCC substrate at the design stage were specified as follows: permittivity of 7.8 ± 0.1 and loss tangent of 0.0014, as given by the manufacturer. Each metal layer from top to bottom is further referred as M1, M2 and M3. The conductivity of M1 and M3 is $5.8 \times 10^7 \text{ S/m}$ and of M2 and of the vias is $2.98 \times 10^7 \text{ S/m}$.

The full antenna is presented in Fig. 2. It consists of 2 radiating dielectric-filled open SIW cavities. Each cavity is fed with TE_{20} mode through a pair of slots and a feeding structure that is described below. After each component is described, the full antenna performance and dimensions will be given. All the simulations below are performed with CST Microwave Studio.

Fig. 1. LTCC layer mapping (“cond” – top metal M1, “cond2” – middle metal “M2”, “resi” – bottom metal M3).

Fig. 2. 2x1 antenna array.

B. Same layer launcher

The antenna is fed from the bottom layer M3 through a CPWG-to-SIW launcher [7]. The sketch of the back-to-back test launcher and its simulated performance is presented in Fig. 3. The back-to-back insertion loss is shown to be better than 0.5 dB and the return loss is better than 20 dB.

Fig. 3. Back-to-back same layer launcher performance.

C. Equal power splitter and TE_{10} -to- TE_{20} mode converter

After the energy is launched into the SIW waveguide, it is divided into two symmetrical cavities containing a symmetric pair of slots. The slots have to be excited out-of-phase to produce a sum radiation pattern and therefore the splitter which is excited with TE_{10} mode should equally split and convert energy into TE_{20} simultaneously suppressing the TE_{10} mode.

The designed splitter is shown in Fig. 4 and its simulated performance in Fig. 5. The simulation is performed taking into account symmetry of the structure with respect to yz-plane and symmetric excitation of TE_{10} mode of port 1. By optimising positions of the posts the return and insertion loss of TE_{10} mode were ensured to be better than 20 dB for the 71-76 GHz frequency band. The conversion from TE_{10} to TE_{20} is 3.2 dB and the symmetry of excitation ensures that the power is equally divided into the both arms.

Fig. 4. Equal power splitter and converter from TE_{10} to TE_{20} mode.

Fig. 5. The splitter-converter simulated performance. Modes (2) – TE_{20} , (1) – TE_{10} .

D. Radiating element

The TE_{20} mode excites it the pair of slots with a dielectric cavity on top of them, see Fig. 6. The slots are matched by positions of two tuning posts and back wall of the cavity. The energy travels through the slots into open cavity laterally bounded by via fence in order to suppress surface wave propagation. This cavity is approximately quarter wavelength long and improves the directivity of the antenna element. Our simulation shown 2-3dB improvement of the directivity for the structure with the top dielectric layer in comparison to a slot to

free space interface. The simulated return loss for the structure is better than 16 dB as shown in Fig. 7.

Fig. 6. 2 slot antenna element with open cavity on top of it. This view does not show M2 metal layer and shows only slots in that plane.

Fig. 7. Return loss of the 2 slot antenna element.

The radiation pattern of the 2 slot antenna element is shown in Fig. 8. The directivity of the antenna is about 8 dBi and there is very little frequency dependence of the radiation pattern is demonstrated.

Fig. 8. 3D radiation pattern of 2 slot antenna element with open cavity at 73.5 GHz.

E. Full antenna layout

All the components presented above have been composed into a full antenna with dimensions shown in Fig. 9.

level of cross-polarization is better than 20 dB as shown in Fig. 14.

The gain of the antenna was measured with 3-antenna method by employing two additional 20 dBi standard horn antennas and a power meter. The measured gain varies from 11.9 to 11.3 dBi at 75-77 GHz band, as shown in Fig. 15. The gain is not measured at lower frequencies due to lack of instruments during the measurements. Nevertheless, there is no significant gain variation expected at lower frequencies. The efficiency estimated by subtracting measured gain from simulated directivity is obtained as 85%.

Fig. 13. Comparison of the simulated and measured radiation patterns.

Fig. 14. Measured normalized radiation patterns of copolar and cross-polar components at vertical plane at 72.7GHz.

Fig. 15. Measured gain of the antenna under test.

IV. CONCLUSION

A novel substrate integrated waveguide (SIW) slot antenna for E-band communications has been proposed in the paper. The antenna has been designed at two-layer LTCC substrate in 71-76 GHz frequency band. The measured return loss is below 9 dB at 72 GHz and better than 10 dB in the rest of the band. The measured radiation pattern and the simulated one are in good agreement. The cross-polarization level is below 20 dB and the measured gain is above 11.3 dBi. The proposed antenna can be used as a standalone antenna or as an element of a larger array manufactured on a two-layer LTCC substrate.

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REFERENCES

- [1] J. A. Zhang, W. Ni, J. Matthews, C.-K. Sung, X. Huang, H. Suzuki, and I. Collings, "Low latency integrated point-to-multipoint and e-band point-to-point backhaul for mobile small cells," in *2014 IEEE International Conference on Communications Workshops (ICC)*, 2014, pp. 592–597.
- [2] M. B. Gueye, H. H. Ouslimani, S. N. Burokur, A. Priou, Y. Letestu, and A. Le Bayon, "Antenna array for point-to-point communication in E-band frequency range," in *IEEE Antennas and Propagation Society, AP-S International Symposium (Digest)*, 2011, pp. 2077–2079.
- [3] M. K. T. Al-Nuaimi, W. Hong, and Y. Zhang, "Design of high-directivity compact-size conical horn lens antenna," *IEEE Antennas Wirel. Propag. Lett.*, vol. 13, pp. 467–470, 2014.
- [4] I. Papageorgiou, A. Derneryd, L. Manholm, and J. Yang, "An E-band cylindrical reflector antenna for wireless communication systems," in *7th European Conference on Antennas and Propagation (EuCAP)*, 2013, pp. 524–528.
- [5] M. Zhang, J. Hirokawa, and M. Ando, "An E-Band Partially Corporate Feed Uniform Slot Array With Laminated Quasi Double-Layer Waveguide and Virtual PMC Terminations," *IEEE Trans. Antennas Propag.*, vol. 59, no. 5, pp. 1521–1527, May 2011.
- [6] J. Xu, Z. N. Chen, X. Qing, and W. Hong, "140-GHz TE₂₀-mode dielectric-loaded SIW Slot antenna array in LTCC," *IEEE Trans. Antennas Propag.*, vol. 61, no. 4, pp. 1784–1793, 2013.
- [7] D. Zelenchuk, A. J. Martinez-Ros, T. Zvolensky, J. L. Gomez-Tornero, G. Goussetis, N. Buchanan, D. Linton, and V. Fusco, "W-Band Planar Wide-Angle Scanning Antenna Architecture," *J. Infrared, Millimeter, Terahertz Waves*, vol. 34, no. 2, pp. 127–139, Jan. 2013.