3rd International Conference on Automation, Control, Engineering and Computer Science (ACECS'16)

Proceedings of Engineering & Technology (PET)
pp. 830-833

Broadband Cross Elevated Patch Antenna

Adel Saad Emhemmed[1], Nuredin Ali Ahmed[2], Khaled Elgaid[3]
[1] Electrical and Electronic Engineering Department, University of Tripoli, Tripoli, Libya, dr.adel.elec@gmail.com
[2] Department of Computers and System Engineering, Azzaytuna University, Tarhona, libya, nuredin@mtit.com.ly
[3] Department of Electronics and Electrical Engineering, University of Glasgow, Glasgow,UK, kelgaid@elec.gla.ac.uk.

***Abstract*—This paper present a new design of broadband cross elevated patch antenna fed by coplanar waveguide. The antenna is designed for MMICs applications at G-band (140GHz to 220GHz). The proposed antenna is composed of coplanar waveguide feed line, air-bridges, a feeding post, supporting posts, and a radiator. The elevated antenna is fed with a gold feeding post connected to a CPW line on top of GaAs substrate. The antenna fabrication is based on a standard III-V MMIC airbridge technology. The antenna topology effectively creates a low dielectric substrate and undesired substrate effects can be eliminated, since the antenna substrate is essentially air and can be used on most substrates to monolithically integrate. The simulated and measured return loss shows a 10dB bandwidth from 203GHz to 211.7GHz achieving a bandwidth of 8.7GHz with maximum directivity observed at the bidirectional beams is 4.1dB**

***Index Terms*— mm-wave elevated patch antenna, reconfigurable patch antenna, G-band antenna, MEMS antenna.**

I. INTRODUCTION

The intensive development and wide application of new generations of communication systems have increased the demand for new antenna designs. The most common requirements of these systems pose on antennas are broad bandwidth, high radiation efficiency, small size, and suited to integration with integrated circuits and MMICs [1, 2]. The needs for larger bandwidth and small size antenna have pushed the wireless communications systems to higher frequency bands in the mm-wave region. The high frequencies of mm-wave as well as their propagation characteristics make them today an excellent choice to satisfy actual requirements imposed by modern wireless communication systems, such as small profile, high data rates, low cost, and short radio links [3, 4]. Also, the high frequencies of mm-waves antennas make them useful for a variety of applications including very high-resolution passive and active imaging applications, very high-speed wireless communication, and systems for detection of concealed weapons. However, the most significant factor impacting on the current applications is the natural absorption spectrum in Earth's atmosphere. Various molecular, atomic, and nuclear resonances occur at different frequencies, creating a variety of unique applications [5]. Printed mm-wave antennas are largely adopted for wireless communication systems, since the shorter wavelength of mm-wave frequencies results in boarder bandwidth and smaller antennas size, avoiding the need for bulky horn antennas and its associated losses resulting from routing signals off-chip to transition from the active MMIC to the horn [4, 6].

The substrate of printed antennas plays a very important role in achieving desirable electrical and physical characteristics. For good antenna performance, a thick substrate with low dielectric constant is desirable since this provides better efficiency. However, to integrate the antenna with other MMICs at mm-waves region, a high dielectric substrate will be used, which causes high surface wave loss due to the thickness of substrates becoming electrically thick [1]. This would result negatively on the efficiency and bandwidth of the antenna. Further, if a thin substrate is used to overcome the loss due to this trapping, another problem arises. A 180 degree phase shift comes from the reflection at the bottom conductor, causing the radiation to cancel out at the driving point. [6-14]. Therefore, to improve the antennas performance, various techniques have been discussed. In order to reduce the effective of the antenna substrate, several methods have been reported such as stacking substrates and coupling through aperture [1, 2], using bulk micromachining to make a cavity underneath and around antenna patch [7, 12], electronic bandgap (EBG) structure [8], or suspending the patch antenna over an air cavity using a membrane or using supporting posts [9-12]. The elevated antenna approach can be considered as an alternative to a conventional printed antenna approach, with concomitant advantages of low loss, broad bandwidth, and reduced dependence on substrate effects.

Cross elevated patch antennas, as compared to other elevated antennas, have the advantage of wider bandwidth and the bidirectional radiation patterns. This paper provides a new design of an elevated cross elevated patch antenna fed by a CPW for G-band applications. The main goal of this new design is to reduce the substrate effect with emphasis on integration the antenna with other MMICs.

II. ANTENNA DESIGN

The geometry of the proposed antenna is shown in Fig.1. The antenna structure consist of CPW feed line, air-bridge, supporting posts, a feeding post, and four triangle radiators. The triangle radiators are elevated by the gold posts to offer a mechanically strong and to reduce the substrate effects. Parameters such as flare angle of the bow and dimensions of the antenna are optimized to enhance the performance of the antenna. The elevated antenna was fed with feeding post connected to a CPW line on top of GaAs substrate because it has many advantages at mm-wave over microstrip type feed lines such as low radiation loss, less dispersion, less dependence of the characteristic impedance on the substrate height and permittivity, and the ease of integration of active and passive circuit elements.

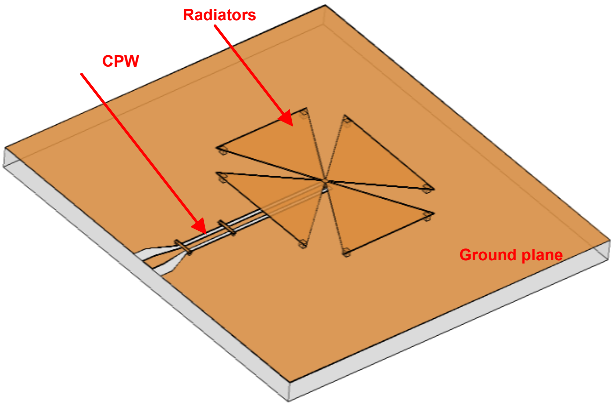

Fig. 1 Geometry of the cross elevated patch antenna

The CPW was designed to have an input impedance of 50Ω to couple the antenna effectively with the measurement system, and its dimension was calculated using ADS software as follows: S-W-S =15-20-15 µm. The CPW ground plane on top of SI-GaAs substrate will act as reflecting, and will totally shield the antenna from the underlying elements and vice versa. This topology effectively creates a low-dielectric constant and substrate undesired effects can be eliminated, since the antenna substrate is essentially air (the lowest possible dielectric constant). This will help increase the radiation efficiency, gain, and the radiation bandwidth. In addition, the type, thickness and stack of the substrates can be varied without significant change of antenna performance. This will allow the use of high dielectric substrates with different thicknesses. 3D HFSS software is used in the design simulation of this antenna

III. FABRICATION

The antenna fabrication is based on a standard III-V MMIC airbridge technology The antenna was fabricated on a GaAS substrate with a thickness of 630µm and a dielectric constant of 12.9 based on surface micromachining technology. Fig. 2 shows the SEM image of the fabricated antenna.

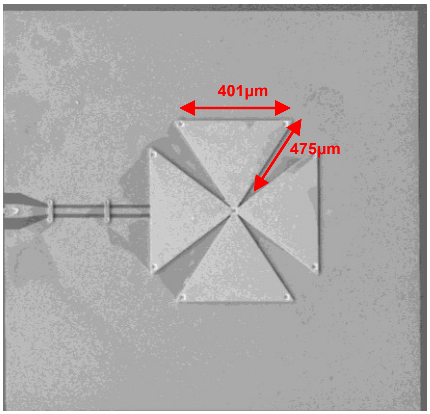

Fig. 2. SEM photo of the fabricated antenna

Two steps were required to realize the proposed structures. First the ground plan was realized by e-beam lithography techniques. This was done by exposing a spun PMMA on the GaAS followed by development, metallization of 1.2µm and liftoff. The second step is using photolithography techniques, incorporating two different photoresists thickness followed by electroplating 2µm gold. The fabrication process is compatible with both III-V and Si MMICs process technology.

IV. RESULTS

The return loss of the elevated patch antenna was measured using an agilent vector network analyzer with coplanar probes with *100µm* pitch size.

Fig. 3 shows the simulated and measured return loss of the 5.5µm cross patch height, the simulated and measured return loss shows a 10dB bandwidth from 203GHz to 211.7GHz achieving a bandwidth of 8.7GHz. The maximum directivity observed at the bidirectional is 4.1dB as shown in Fig 4 showing a good radiation efficiency of this design, and almost frequency independent radiation pattern across antenna bandwidth. The introduced antenna takes advantage of the elevated patch antenna to eliminate surface waves to get better radiation performance and advantage of bowtie antenna to improve the bandwidth.

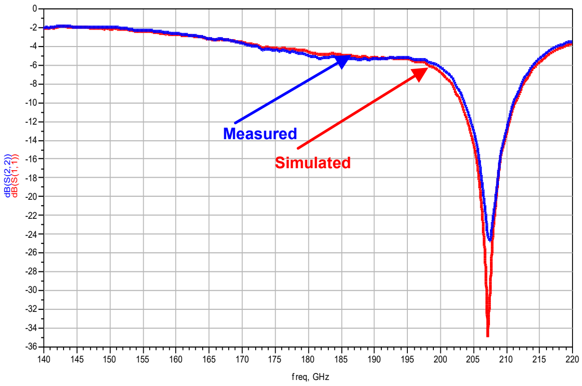

Fig. 3 Measured and simulated return loss of cross antenna

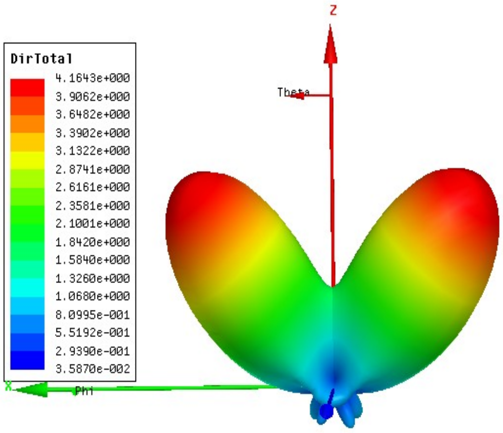

Fig. 4 Simulated 3-D radiation pattern for the antenna directivity

V. CONCLUSION

The important feature of the cross elevated patch antenna presented in paper is that it is easy to fabricate using two level fabrication processes and RF signal can be connected between the signal and grounds of CPW port. Also, the antenna design is a solution reduces undesired substrate effects, and a viable route to higher levels of integration and functionality problem. To our knowledge, this is the first ever-reported cross elevated patch antenna operating at G-band frequencies and fabricated on high dielectric substrate.

REFERENCES

[1] F. Croq and D. M. Pozer, ''Millimeter-Wave Design of Wide-Band Aperture-Coupled Stacked Microstrip Antenna'', IEEE Transactions on Antennas and Propagation, Vol. 39, No. 12, 1991..

[2] G. P. Gauthier and L. P. B. Katehi, ''A 94-GHz Aperture-Coupled Micromachined Microstrip Antenna'', IEEE Transactions On Antennas And Propagation, Vol. 47, No.12, 1999.

[3] H. LiQuan, ''Some Advances In Millimeter Wave Application Systems'', IEEE Asia Pacific Microwave Conference, pp. 749-752, Dec 1997.

[4] S. Gunnarsson, N. Wadefalk, J. Svedin, S. Cherednichenko, I. Angelov, H. Zirath, I. Kallfass, and A. Leuther, '' A 220 GHz Single-Chip Receiver MMIC With Integrated Antenna'', IEEE Microwave and Wireless Components Letters, Vol. 18, NO. 4, pp. 284-286, Apr 2008.

[5] Matthew A. Morgan, ''Millimeter-Wave MMICs and Applications'', PhD thesis, California Institute of Technology, 2003.

[6] D. M. Pozer, ''Consideration for Millimetre Wave Printed Antennas'', IEEE Transactions on Antennas and Propagation, Vol. AP-31, NO. 5, pp. 740-747, 1983.

[7] I. Papapolymerou, R. Drayton, and L. Katehi, ''Micromachined Patch Antennas'', IEEE Transactions On Antennas And Propagation, Vol. 46, NO. 2, pp. 275-283, Feb 1998.

[8] Y. Lee, X. Lu, Y. Hao, S. Yang, R. Ubic, J. Evans and C. Parini, ''Directive Millimetre-wave Antenna Based on Free Formed Woodpile EBG Structure'', IEEE Electronic Letters, Vol. 43, No. 4, pp. 195-196, Feb 2007.

[9] H. Lee, J. Kim, S. Hong, and J. Yoon, ''Micromachined CPW-Fed Suspended Patch Antenna For 77 GHz Automotive Radar Applications'', IEEE European Microwave Conference, Vol. 3, pp. 249-252, Oct 2005.

[10] Bo Pan, Y. Yoon, J. Papapolymerou, M. Tentzeris and M. Allen, ''Design and Fabrication of Substrate-Independent Integrated Antennas utilizing Surface Micromachining Technology'', IEEE Microwave Conference Proceedings, Vol. 2, Dec 2005.

[11] Y. Yoon, Bo Pan, J. Papapolymerou, M. Tentzeris, and M. Allen, '' Surface-micromachined millimeter-wave antennas'', IEEE The 13th International Conference on Solid-State Sensors, Actuators and Microsystems, Vol. 2, pp. 1986-1989, Jun 2005.

[12] A. Courtay, G. P. Gauthier and G. M. Rebeiz, ''Microstrip Antennas on Synthesized Localized Low Dielectric Substrates'', IEEE Transactions on Antennas and Propagation, Vol. 45, NO. 8,1997.

[13] I. Venneri, A. Borgia, L Boccia, G Amendola, and G. Di Massa, '' Millimeter waves patch antenna design and realization on BCB polymer substrates'', IEEE Antennas and Propagation Society International Symposium, Jul 2008.

[14] S. Ranvier, S. Dudorov, M. Kyro, C. Luxey, C. Icheln, R. Staraj, and P. Vainikainen, '' Low-Cost Planer Omnidirectional Antenna for mm-Wave Applications'', IEEE Antennas and Wireless Propagation Letters, Vol. 7, pp. 520-522, Dece 2014.