Wide Band Microstrip Patch antenna for fast switching and 5G Application

[1]Jitendra Ahir, [2]Dr. Sanjeev Kumar

[1]Asst Professor, [2]Professor
Department of Electronics and Communication Engineering
Rabindranath Tagore University
Raisen (MP), India.

***Abstract*- The proposed microstrip patch antenna for Si substrate in CMOS technology is proposed, the top of a proposed antenna is loaded with fractal shape and the reflector is a ground. The antenna is fed at a center of the excited patch the antenna is compact in size and easily fabricated through photolithography. The substrate used in a antenna is SI whose permittivity is 12.5. The micrpostrip patch antenna is operated in a THz frequency ranging from 22 to 50 GHz. The antenna is operated in a hybrid mode because of this the gain of an antenna is to be improved such mode show the -10 db bandwidth as well as -3db gain and directivity of a proposed antenna. The antenna is operated in a Tera hertz which is suitable for wide gain and high bandwidth for a Terahertz frequency application. The dimension of the via hole is 1.6mm (1600 micro meter). The excited patch and reflector is separated by a feeding probe or SMA connector of 50 ohms. The impedance matching between source to load is done through loading the open wire of dimension 1.6mm,**

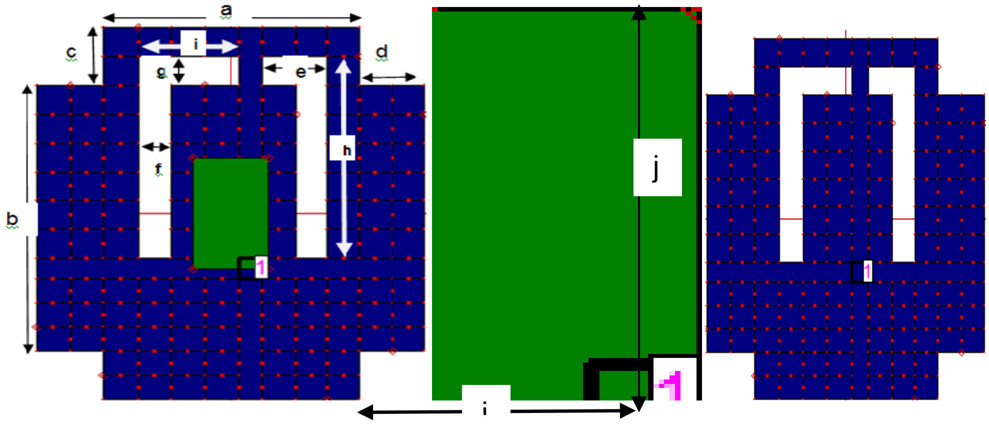
***Keywords*- CMOS, Rectangular patch antenna, Microstrip patch, terahertz (THz), wideband.**

I. INTRODUCTION

The terahertz antenna are widely used in a security aspect like high speed data communication, short range detection of target, medical emergency like cancer detection and many more. [1-4]. The terahertz is generally varied in between microwave and infrared spectrum . the frequency generally used in a tera hertz is 0.1 to 10 THz [5-9] .desktop In THz applications, the proposed antenna is small in size and lower , the devise is used to reduced the paracitic effect due to single component used no external wire is bonding because of this it is used in a various application where mutual coupling is less [6] this paper From previous work the antenna is used in a radio communication is in on chip. The substrate used in an antenna is silicon substrate (εr = 11.7~11.9). Most of the power from the are reflected and its directed into the substrates, most important is to be back radiation and lower gain because of the performance of an antenna is lower down [8].However, for high substrate constant and huge thickness silicon material confine huge power and result the electromagnet waves serve on substrate. Due to this the radiation pattern is distorted and degrades the antenna gain. As a result, predictable on-chip antennas experience from huge losses, distorted patterns, and gain reduces, which is on average limited to 0 dBi [10]. For improving the gain and radiation parameter, the different techniques have been reported. One of the simple techniques is used to reflected ground plane consider as a shield to remove the effect of losses in a substrates [11]-[12].The solutions include artificial magnetic conductor arrangement [13]-[14], near to the ground loss silicon-based substrates [15] or GaAs [16] , Hollow silicon substrate [17], silicon lenses [18]-[19] and 3D antenna [20]. These techniques are efficient, but, also with inadequate antenna gain or more cost it is not appropriate for mass production.The Dielectric resonator antenna (DRA) is an alternative antenna to improve the gain of on chip antenna and achived approximately higher gain that is more than 8dbi as per previous work. [21]-[25]. But the DRA is designed only for single band operation also it has narrow bandwidth and it is difficult to designed such antenna for tera hertz frequency due to miniature size. [21], [23]-[25], recently, a chip-scale Dielectric Resonance Antenna is operated at very high frequency operated at 280 GHz was presentedt [26], the proposed antenna is design and simulated to achived a stable frequency range , stable radiation pattern and high gain but in previous work the directivity is not come in a research but in our proposed work we will work on this and achived better directivity as compare to previous work. However, the design is very simple and suitable for THz frequency. The antenna is simulated in IE3d Software Section II. The proposed antenna and its 3D animation is to be display and observed that the radiation pattern is stable.. Simulations result show that the −10 dBi impedance bandwidth and 3-dB gain bandwidth are 55%. Meanwhile, the directivity is about 9 dBi. As per the literature survey it is the wide band for on chip antenna working to the best knowledge of the author. In section III. The measured results in software are then illustrated in Section IV. Finally, a conclusion is given

II. ANTENNA DESIGN

The proposed antenna for wideband in THz is as shown in figure 1. The antenna with different dimension of an antenna with defected ground palne and radiating plate is as shown in figure1. The proposed antenna is design by using silicon substrate of 1.6mm thickness and permittivity is (εr = 11.7~11.9), the proposed structure is simulated on IE3D software



(a) (b) (c)

Figure 1. Structure of proposed antenna (a) Top view of (b) Radiating Patch (c) Ground Plane

Table1 Design specifications [5]

Parameters	(mm)	Parameters	(mm)
a	8	g	1
b	10	h	7
c	2	i	2.5
d	2	j	3.8
e	2		
f	1		

The dimension and structure of porposed antenna is as shown in fig-1. The antenna is truncated at the corner and consists of two slot to improve the gain as well as directivity. In figure the (a) shown the top view of an antenna (b) shown the radiating patch or exciting patch and (c) shown the defected ground plane. The antenna seprated the radiating patch and exciting patch by silicon substrate the antenna is coaxial or 50 ohms feeding is used. At higher frequency it is easily to switching at a very high rate because the frequency used in a THz.

Table 1. As shown above the different dimension of the proposed antenna.

III. ANTENNA SIMULATION AND MEASURED RESULT

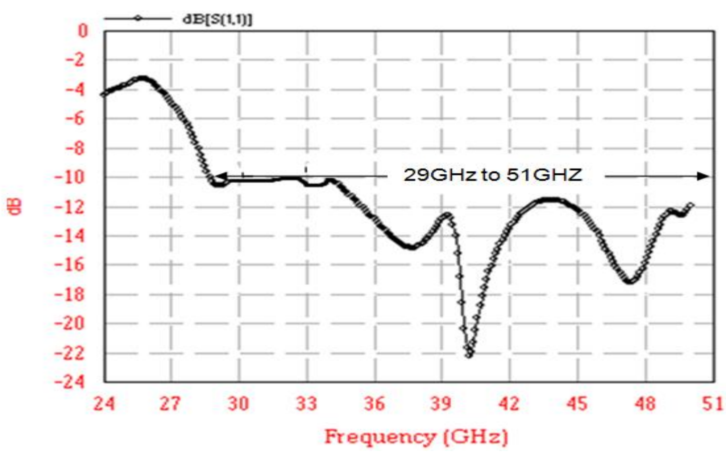


Figure 2 Simulated Reflection Coefficient versus frequency plot of proposed antenna

From Fig 2 the graph is understandable that the proposed antenna reflection is very less from load to source at frequency ranges from 29GHz to 51GHz and the antenna is stable for this frequency range. The designed antenna is operated a single band from 29 to 51 GHz. The antenna is simulated in IE3d and the VSWR bandwidth of an antenna is 55% of single band operation. The dip of return loss of the proposed antenna is -22 dB. By changing the position or by coaxial feed line we can change the bandwidth of an antenna but at proper setting the feed point and slot area we can improved or tune the antenna as per our required frequency band

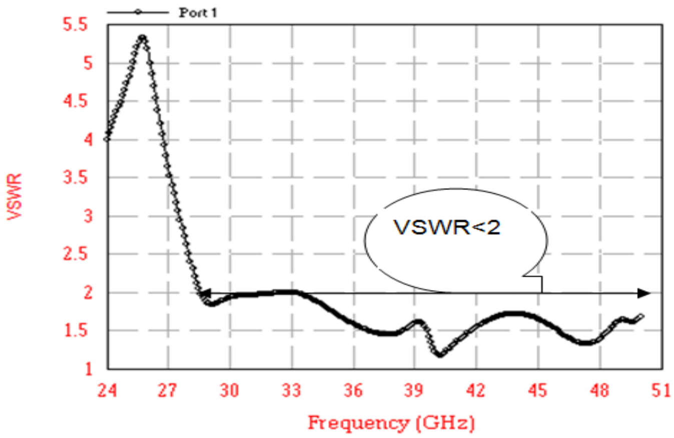


Figure 3 Simulated Result for VSWR versus frequency plot of proposed antenna

The VSWR nad frequency response of an antenna is as shown in fig.3. The voltage standing wave is stable or less than 2 for frequency range 29 to 51 GHz. According fig 3 it is shown that the VSWR bandwidth of a proposed antenna is 55% and as per previous paper it is 5% more achived as per simulation result. The proposed antenna is suitable for 5G application and all other application which is required a band for 29GHz to 51 GHz.

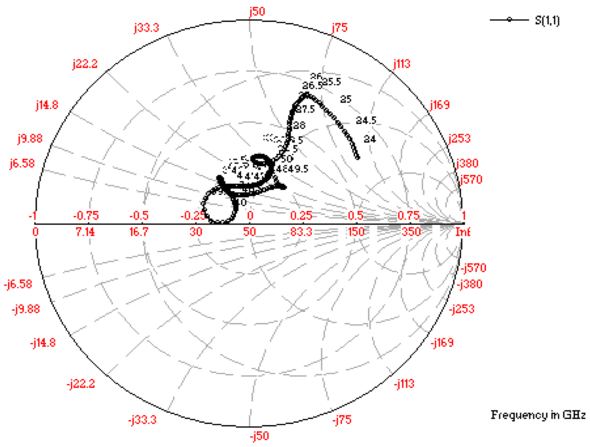


Figure 4 Simulated Result for Smitch Chart of proposed antenna

The fig shown the inductive loading of the proposed antenna the Inductive matching is done the complete graph is shifted to upper part of the chart so it shown that the antenna is inductive loading and resonance at 29 to 51 GHz.

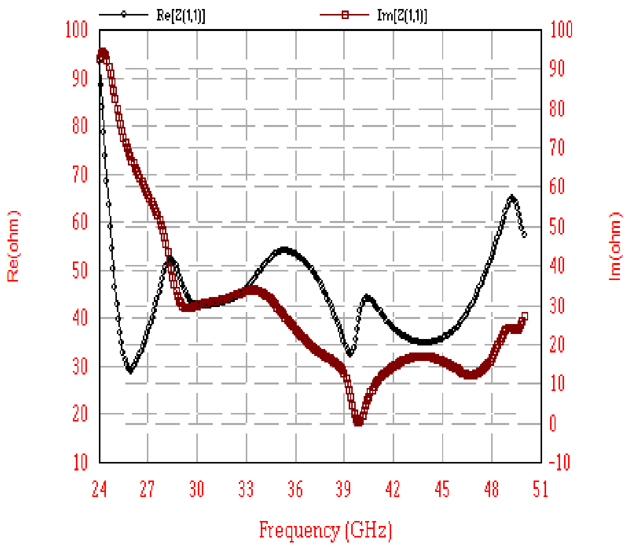


Figure 5 Simulated Result for Real and Imaginary resistance of proposed an antenna

The working principal of the proposed antenna, total impedance in term of feeding impedance *Z*11 and resistance R11 are as shown in Fig. 5. The resonances of an antenna from frequency 29 to 51 GHz are observed, where the resonance shown that the input impedance is should be equal to input resistance means only maximum usable frequency is used for the communication.

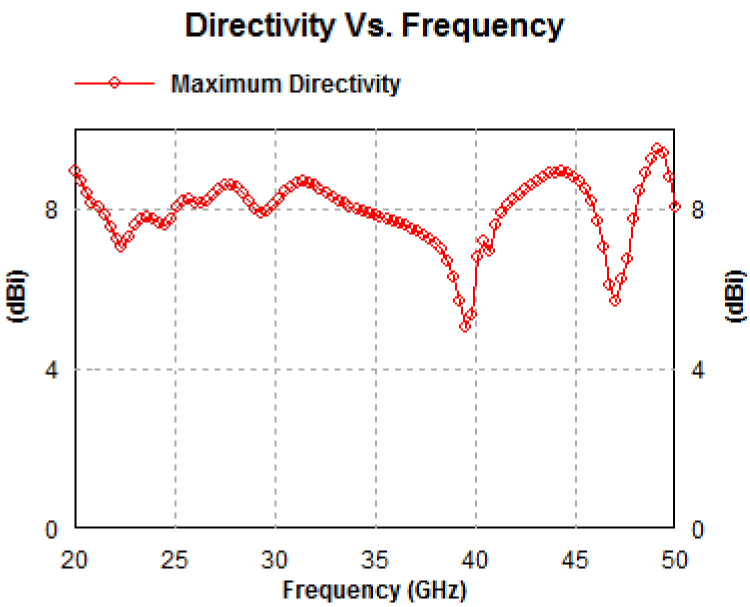


Figure 6 Simulated Result for Directivity of proposed antenna

The simulation result for an proposed antenna directivity is as shown in fig 6. The antenna is simple in structure and obtained higher directivity as compared to previous work. The directivity of an antenna is approximately 9 dBi from 29 to 51 GHz. The directional of an antenna in term of directivity is obtained with respect to far end radiation pattern. The area with respect to beam and directivity both are inversely proportional to each other, mean directivity increase with decreased in beam area

.

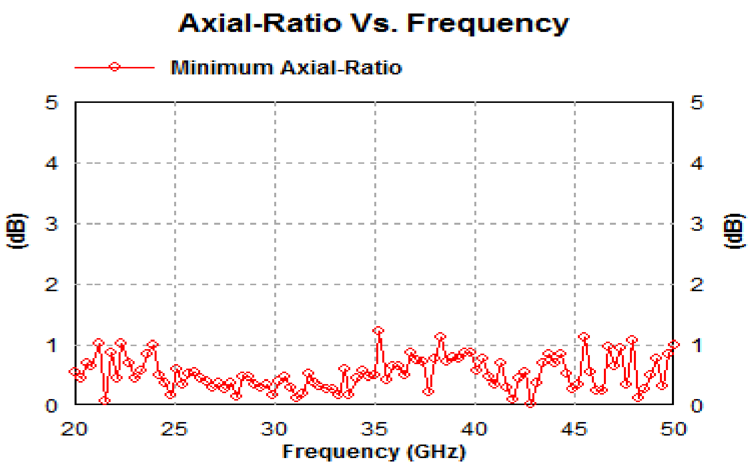


Figure 7 Simulated Result for axial ratio of proposed antenna

Axil ratio show the polarization of an antenna. The axial ratio is obtained with respect to azimuth and elevation of an angle. The polarization and axial ration bandwith is to be broad by sloting the antenna. From the fig it is clear that the antenna magnitude is varied in between 1 and 0 so we can say that the antenna is stable for circular polirization. The axial ratio is an orthogonal component of electric and magnetic field with respect to elevation and azimuth angle.

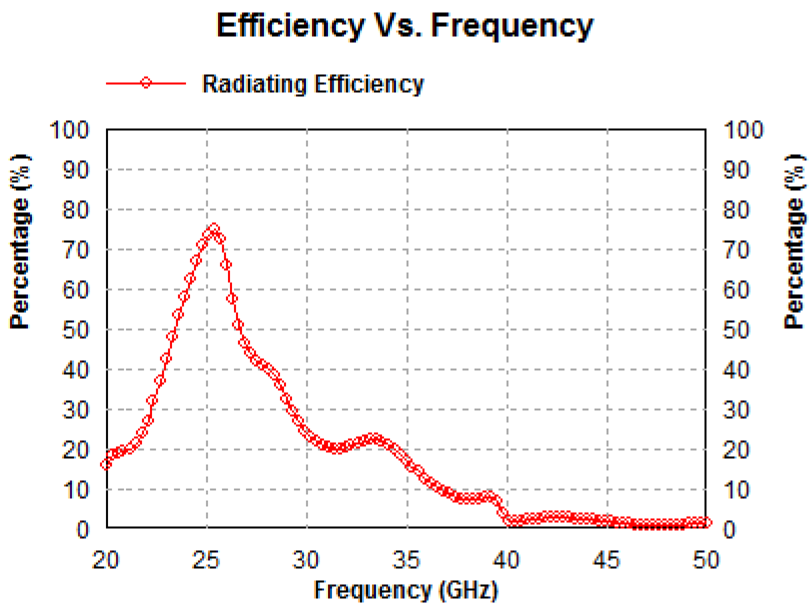


Figure 8. Radiation Efficiency of a design antenna

The distant radiation pattern of a proposed antenna is drive by using the relation of (R>> $2D^2/\lambda$) The D is defined as a directivity of an antenna. The radiation efficiency of design antenna is as shown in fig 8. It is clear that the proposed design is stable for a single band and radiation efficiency of an antenna is approximately 70%

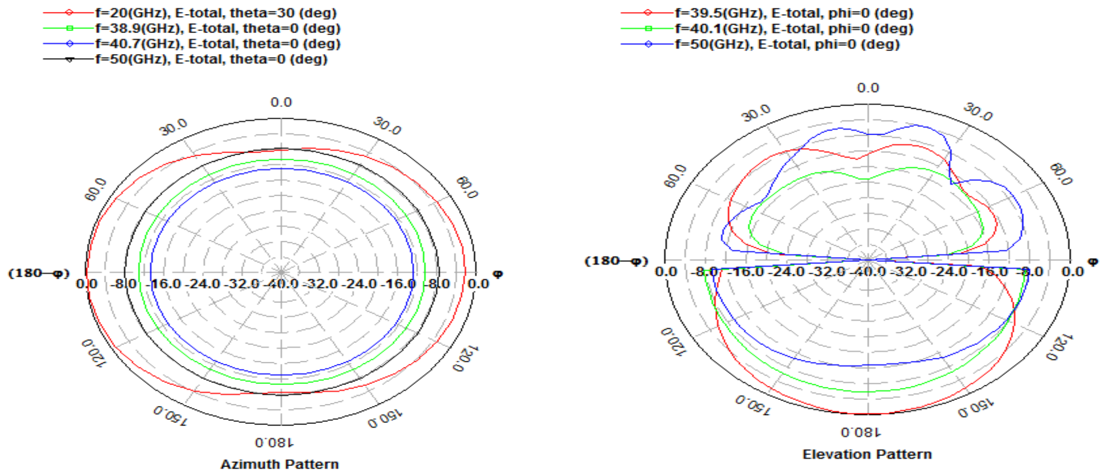


Figure 9 Simulated Result for azimuth and elevation pattern

The design antenna radiation pattern for far field radiation for maximum less return loss for 8.2 GHz and 9.2 GHz. The elevation angle from 0 to 180 and azimuth angle 0 to 360 degree is introduced for simulation purposed. The antenna is stable for this frequency. The antenna radiation also improved by introducing some additional parasitic element in between exciting patch and ground. The ground is finite so that the maximum output is in free space such effect is known as fringing effect

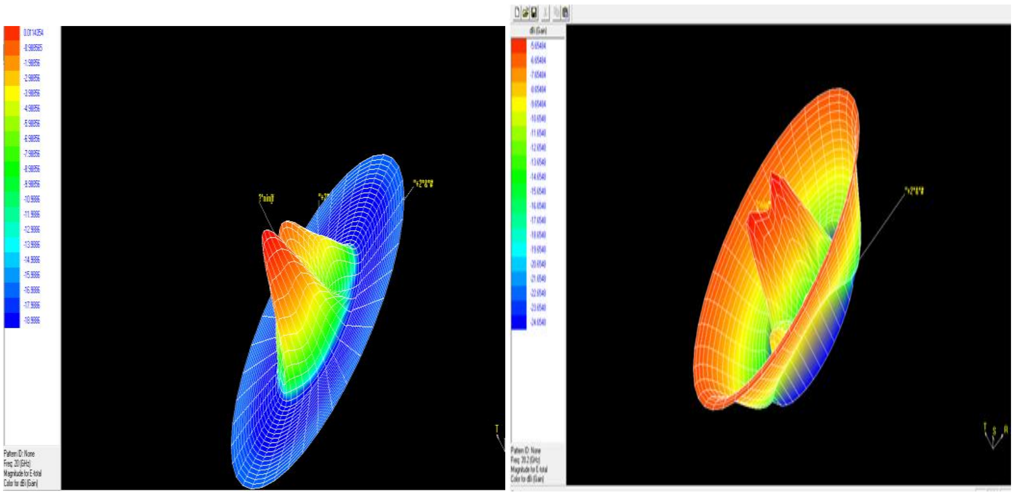


Figure 10 3D Radiation view of an proposed antenna

The 3D view for an proposed antenna with radiation pattern as shown in fig 10 the antenna is simulated for Tera hertz frequency application and the antenna is suitable for fast switching and stable the entire Single band as shown in fig.10

IV. CONCLUSION

In this article, wide band terahertz on-chip antenna for terahertz frequency application the design is novel and compact for circular polarization. The antenna is suitable for 29 to 51 GHz frequency. The antenna is suitable for 5G application and fast switching in term of semiconductor devices. The simulation parameter of an antennas is observed in this designed are discussed with other THz antennas and simulation results show the enhancement in conditions of an antenna parameter would be a potential applicant for recent THz applications, such as spectroscopy, sensing, medical diagnosis, and high data rate wireless hotspots.

REFERENCES:

[1] Libin Sun,Yue Li,Zhijun Zhang, (2022), "Wideband Dual Polarized Endfire antenna based on compact open ended cavity for 5G Mm Wave Mobile Phones." *IEEE Transaction on antenna and propagation,* Vol 70, no 3,pp1632-1642,

[2] Inzamam Ahmad , Sadiq Ullah , Adnan Ghaffar ,Mohammad Alibakh shikenari , Salahuddin Khan and Ernesto Limiti, (2021), "Design and Analysis of a Photonic Crystal Based Planar Antenna for THz Applications*," Electronics 10,* https://doi.org/10.3390/electronics10161941.

[3] R. Han, Z. Hu, C. Wang, J. Holloway, X. Yi et al., (2019). "Filling the gap: silicon terahertz integrated circuits offer our best bet," *IEEE Microw.Mag.*, vol. 20, no. 4, pp. 80-93,

[4] H. Elayan, O. Amin, B. Shihada, R. M. Shubair, and M.-S. Alouini, (2020)."Terahertz band: the last piece of RF spectrum puzzle for communication systems," *IEEE Open J. Commun. Soc.*, vol. 1, pp. 1-32,

[5] S.-X. Huang, Y.-S. Zeng, G.-B. Wu, K.-F. Chan, B.-J. Chen et al., (2020)."Terahertz Mueller matrix polarimetry and polar decomposition," *IEEE Trans. THz Sci. Technol.*, vol. 10, no. 1, pp. 74-84,

[6] L. Cheng, L. Wang, H. Mei, Z. Guan, and F. Zhang, (2016). "Research of nondestructive methods to test defects hidden within composite insulators based on THz time-domain spectroscopy technology," *T-DEI*, vol. 23, no. 4, pp. 2126-2133,
[7] K. K. Tokgoz, S. Maki, J. Pang, N. Nagashima, I. Abdo et al., (2018), "A 120Gb/s16QAM CMOS millimeter-wave wireless transceiver," *in 2017 IEEE Int. Solid-State Circuits Conf.*, pp. 168-170.
[8] A. Dyck, M. Rosch, A. Tessmann, A. Leuther, M. Kuri et al., "A transmitter system-in-package at 300 GHz with an off-chip antenna and GaAs-based MMICs," *IEEE Trans. THz Sci. Technol.*, vol. 9, no. 3, pp. 335-344, 2019.
[9] J.-Y. Zhong, W.-J. Lin, J.-H. Cheng, Y.-H. Kung, J.-P. Chen et al., (2019). "A high spectral efficiency receiver at 57-66 GHz using 65-nm CMOS in LTCC package with Polarization MIMO," *IEEE Access*, vol. 7, pp. 129466-129479,
[10] H. M. Cheema, and A. Shamim, (2013). "The last barrier: on-chip antennas," *IEEE Microw. Mag.*, vol. 14, no. 1, pp. 79-91,
[11] S. Hu, Y.-Z. Xiong, B. Zhang, L. Wang, T.-G. Lim et al., (2012). "A SiGe BiCMOS transmitter/receiver chipset with on-chip SIW antennas for terahertz applications," *IEEE J. Solid-State Circuits*, vol. 47, no. 11, pp.2654-2664,
[12] P. Burasa, T. Djerafi, N. G. Constantin, and K. Wu, (2017). "On-chip dual-bandrectangular slot antenna for single-chip millimeter-wave identification tag in standard CMOS technology," *IEEE Trans. Antennas Propag.*, vol. 65, no. 8, pp. 3858-3868,
[13] L.-J. Xu, F.-C. Tong, X. Bai, and Q. Li, (2018). "Design of miniaturised on-chip slot antenna for THz detector in CMOS," *IET Microw. Antennas Propag.* ,vol. 12, no. 8, pp. 1324-1331,
[14] H. Jalili, and O. Momeni, 2017, "A 318-to-370GHz standing-wave 2D phased array in 0.13µm BiCMOS," in 2017 *IEEE Int. Solid-State Circuits Conf.*, pp. 310-311.
[15] M. S. Khan, F. A. Tahir, A. Meredov, A. Shamim, and H. M. Cheema, 2019."A W-band EBG-backed double-rhomboid bowtie-slot on-chip antenna," *IEEE Antennas Wirel. Propag. Lett.*, vol. 18, no. 5, pp. 1046-1050,
[16] H. Zhu, X. Li, W. Feng, J. Xiao, and J. Zhang, (2018). "235GHz on-chip antenna with miniaturised AMC loading in 65nm CMOS," *IET Microw. Antennas Propag.*, vol. 12, no. 5, pp. 727-733,
[17] N. André, M. Rack, L. Nyssens, C. Gimeno, D. Oueslati et al., (2019). "Ultralow-loss Si substrate for on-chip UWB GHz antennas," *IEEE J. Electron Devices Soc.*, vol. 7, pp. 393-397,
[18] Y.-H. Baek, L. H. Truong, S.-W. Park, S.-J. Lee, Y.-S. Chae et al., (2009) "94-GHz log-periodic antenna on GaAs substrate using air-bridge structure," *IEEE Antennas Wirel. Propag. Lett.*, vol. 8, pp. 909-911,
[19] W. A. Ahmad, M. Kucharski, A. Di Serio, H. J. Ng, C. Waldschmidt et al., (2019). "Planar highly efficient high-gain 165 GHz on-chip antennas for integrated radar sensors," *IEEE Antennas Wirel. Propag. Lett.*, vol. 18, no. 11, pp. 2429-2433,
[20] X. Gao, J. Du, T. Zhang, and Y. J. Guo, (2019). "High-Tc superconducting fourth-harmonic mixer using a dual-band terahertz on-chip antenna of high coupling efficiency," *IEEE Trans. THz Sci. Technol.*, vol. 9, no. 1,pp. 55-62,
[21] K. Guo, A. Standaert, and P. Reynaert, (2018) . "A 525-556-GHz radiating source with a dielectric lens antenna in 28-nm CMOS," *IEEE Trans. THz Sci. Technol.*, vol. 8, no. 3, pp. 340-349,
[22] P. Starke, D. Fritsche, S. Schumann, C. Carta, and F. Ellinger, (2017). "High-efficiency wideband 3-D on-chip antennas for subterahertz applications demonstrated at 200 GHz," *IEEE Trans. THz Sci. Technol.*, vol. 7, no. 4, pp. 415-423,
[23] C.-H. Li, and T.-Y. Chiu, (2017) "340-GHz low-cost and high-gain on-chip higher order mode dielectric resonator antenna for THz applications," *IEEE Trans. THz Sci. Technol.*, vol. 7, no. 3, pp. 284-294,.
[24] X.-D. Deng, Y. Li, C. Liu, W. Wu, and Y.-Z. Xiong, (2015). "340 GHz on-chip 3-D antenna with 10 dBi gain and 80% radiation efficiency," *IEEE Trans. THz Sci. Technol.*, vol. 5, no. 4, pp. 619-627,
[25] C.-H. Li, and T.Y. Chiu, (2019). "Single flip-chip packaged dielectric resonator antenna for CMOS terahertz antenna array gain enhancement," *IEEE Access*, vol. 7, pp. 7737-7746,
[26] D. Hou, W. Hong, W.-L. Goh, J. Chen, Y.-Z. Xiong et al., (2014), "D-band on-chip higher-order-mode dielectric-resonator antennas fed by half-mode cavity in CMOS technology," *IEEE Antennas Propag. Mag.*,vol. 56, no. 3, pp. 80-89,.
[27] C.-H. Li, and T.-Y. Chiu, (2017) "340-GHz low-cost and high-gain on-chip higher order mode dielectric resonator antenna for THz applications," *IEEE Trans. THz Sci. Technol.*, vol. 7, no. 3, pp. 284-294,.
[28] N. Buadana, S. Jameson, and E. Socher, (2020) "A multiport chip-scale dielectric resonator antenna for CMOS THz transmitters," *IEEE Trans. Microw. Theory Techn.*, early access,.
[29] S. Fregonese, M. Deng, M. De Matos, C. Yadav, S. Joly et al., (2019). "Comparison of on-wafer TRL calibration to ISS SOLT calibration withopen-short de-embedding up to 500 GHz," *IEEE Trans. THz Sci. Technol.*,vol. 9, no. 1, pp. 89-97,
[30] X.-D. Deng, Y. Li, W. Wu, and Y.-Z. Xiong, (2015) "340-GHz SIW cavity-backed magnetic rectangular slot loop antennas and arrays in silicon technology," *IEEE Trans. Antennas Propag.*, vol. 63, no. 12, pp.5272-5279,.