Microstrip Fed Slotted Ground Wide Band Radiator for 5G and High Data Rate Communications

Sreejith M. Nair[1], Manju Abraham[2], Sindhu S[3], Nishamol. M. S[4]

[1]Department of Electronics, Government College Chittur, Palakkad-678104, India
[2]Department of Electronics, BPC College, Piravom, Ernakulam, India
[3]Department of Electronics, Government College Chittur, Palakkad-678104, India
[4]Department of Electronics, Government College Chittur, Palakkad-678104, India

Corresponding Author: **Sreejith M. Nair**

Abstract: A novel microstrip fed slotted ground antenna having wide bandwidth capable of future 5G and high data rate communication application is developed. Antenna offers a wide bandwidth of 4.715 GHz ranging from 2.875 to 7.59 GHz with uniform radiation pattern, uniform polarization characteristics, moderate gain and flat and high radiation efficiency. Developed antenna has an overall volume of 25 × 23 × 1.6 mm^3 which is compact when compared with other antennas having these radiation frequencies. Another attraction of the proposed structure is the simplicity and less number of dimensional aspects and which makes it a suitable candidate in latest generation communication gadgets.

Index Terms: Microstrip, Slotted Ground, 5G, Wideband antenna, Radiation efficiency

1. Introduction

Antenna is considered as the most important part of a communication system because it acts as the gateway of that system to entire world. If antenna performance is poor, whatever advanced technology may be the system having, it is of no use. Now a days we are witnessing a drastic change in the communication field that the size of the communication device is reduced and data rate of the same increasing exponentially. This creates a simultaneous challenge and opportunities to an antenna design engineer. The prime task of the researcher is to design and develop a compact antenna having simple structure without compromising the radiation characteristics. The most required characteristics of a high data rate antenna are the increased bandwidth with uniform radiation behaviour. Many designs are already available in the literatures and a nutshell of the same is discussed as follows.

A tapered slot antenna having a microstrip feed offering a wide band width is discussed in [1], whose overall dimension is very large. In [2 and 3], the authors introduce a microstrip fed slot antenna having UWB characteristics with some band notching. A wideband antenna based on star shaped fractal components is introduced in [4] which is very complex structure. C. L. Mak, K. M. Luk and K. F. Lee in[5] discussing about a wide band antenna whose band width enhancement is obtained using an L shaped probe. A patch antenna having high bandwidth operating at 28 GHz range is introduced in [6]. In [7], authors discussing about a compact microstrip fed monopole antenna having very complex dimensional parts, offering a wide band. A UWB suitable for phased array is discussed in [8] which uses lumped components in addition to planar antenna parts and that makes the structure more complex. Lei Zhu and others in [9] introduces a novel broadband antenna based on slots which offer wide bandwidth, but the radiation characteristics are non uniform. An elliptical slot based wideband microstrip fed antenna is analysed in [10]. A non planar microstrip antenna based on loops and having a directional behaviour is discussed by authors in [11]. A hexagonal slot based printed monopole having a small band width enhancement is given in [12]. A complex structure having wide band and circular polarization is given in

[13] by X. L. Bao and others. Kyungho Chung et al present a U slot antenna having a wide bandwidth with some band notches and non uniform radiation patterns [14]. In [15] a slotted patch antenna fed by a microstrip line is introduces, which is a triple layer structure. A pentagon patch monopole antenna having wide band characteristics is discussed and analysed in [16]. A complex structure based compact antenna suitable for wideband communication is presented in [17]. Two C shaped patch arrangements having enhanced bandwidth is discussed in [18]. A wide band antenna whose bandwidth enhancement is created with the help of a U shaped parasitic element is analysed by X. -P. Chen and others in [19]. In [20], authors presents a quasi spiral antenna having microstrip feed which offers wide band operation but the structure losses its planar characteristics. However, in all the above discussed papers the antenna structure is either complex or huge. If compactness is satisfied, they are of without any uniform radiation characteristics.

In this article we are presenting a simple and novel rectangular slotted ground antenna fed with a standard microstrip feed having a wide range of operating bandwidth ranging from 2.875 GHz to 7.59 GHz suitable for upcoming high data rate communication applications. Proposed structure offers uniform radiation patterns with linear polarization characteristics in the whole bandwidth. When fabricated on FR4, the overall volume of the structure is about 25 × 23 × 1.6 mm^3 which is very compact when compared with other antennas. Parametric analysis of the structure and FDTD computation of the same are performed to analyse the antenna and the result obtained are discussed. Gain and radiation efficiency characteristics of the structure are also very good which makes this antenna a good candidate suitable for modern communication devises.

2. Geometry of the Antenna

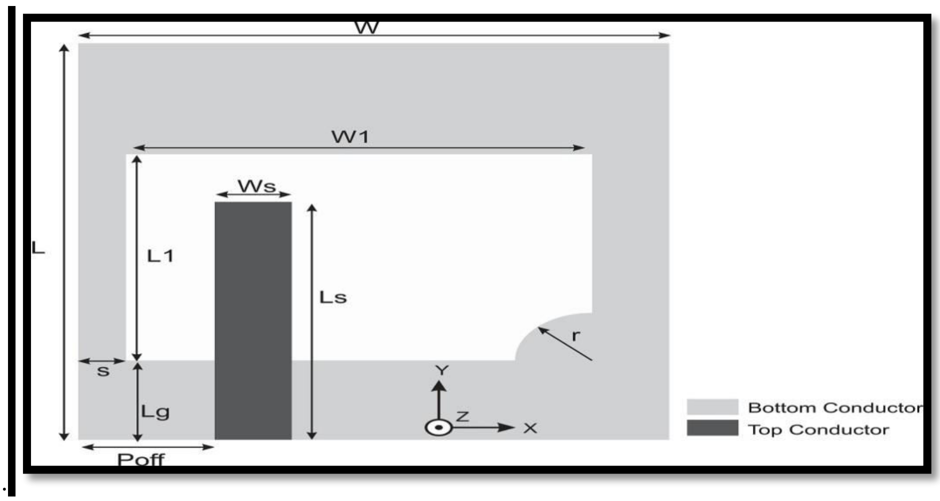

Fig.1. Proposed wide band Antenna Structure

Proposed antenna geometry is derived from an offset fed microstrip monopole, whose ground plane is truncated by introducing a rectangular slot on it to generate multiple resonances. To betterment the matching and to increase the bandwidth of the antenna, a quarter circle is integrated at one bottom corner of the ground slot. Structure of the antenna in detail is depicted in Fig.1.

To optimize the physical dimensions, a set of parametric studies are performed using Ansoft HFSS simulation software and the results obtained are discussed in next session.

3. Parametric Studies

As the first step of parametric analysis, signal strip length Ls of the structure is varied by keeping all other dimensions constant. The effect of Ls on resonance and band width is shown in Fig.2. It is clear from the figure that all the resonances comes to lower side with this parameter and matching if the antenna is drastically changing with this. Thus it will be crucial in determining the bandwidth of the antenna.

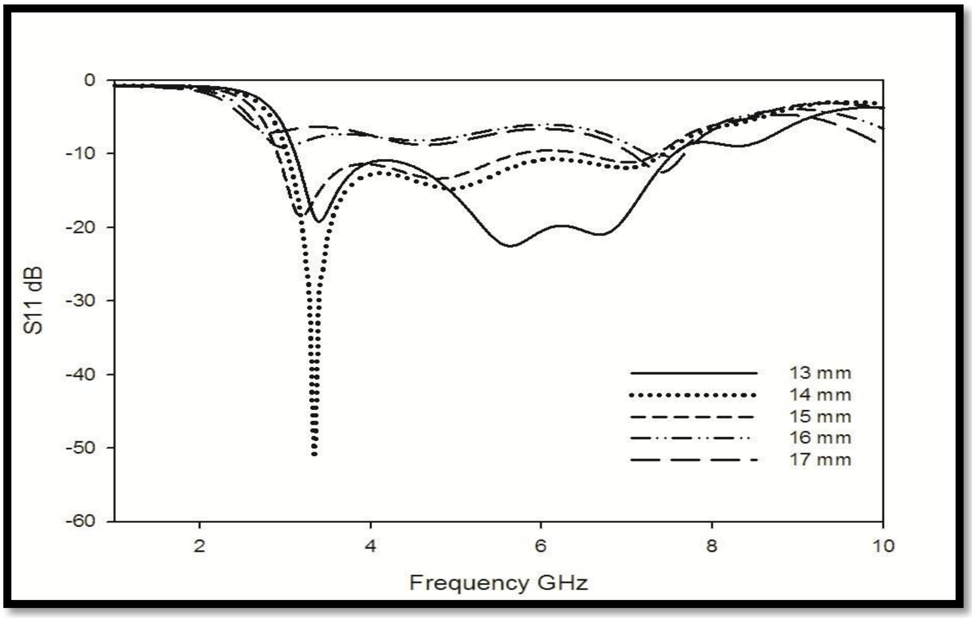

Fig.2. Effect of Ls on resonant frequencies

Variation of S11 with ground length L of the structure is depicted in Fig.3. It is evident from the figure that the first and third resonance keeping unaltered with this parameter, while the second resonance shows a constant down shift with L. Impedance matching of the structure also increases with ground length.

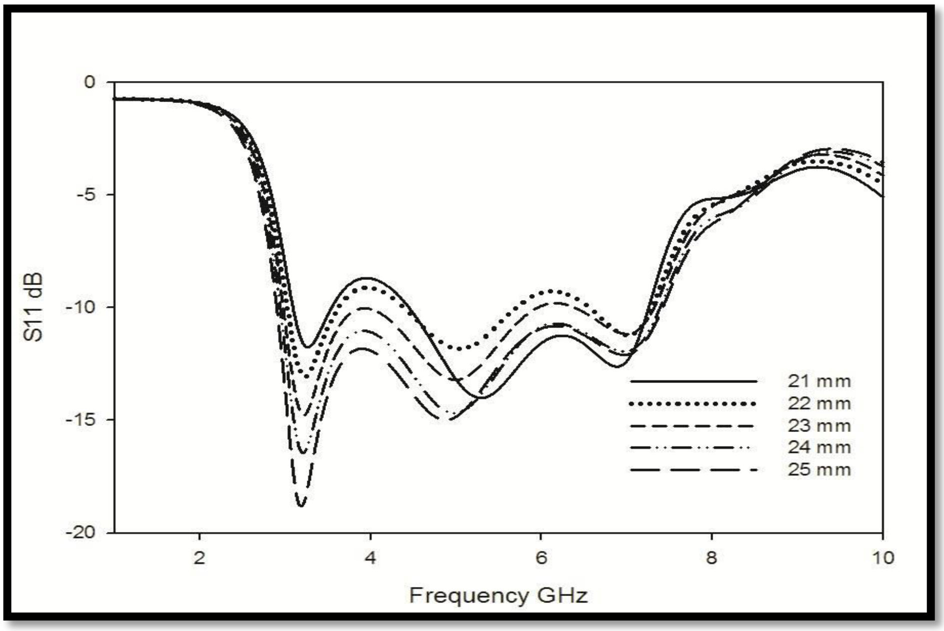

Fig.3. Effect of L on resonant frequencies

Effect of ground width W on resonances is given in Fig.4 and in which the first two resonant positions are almost constant with W, but third resonance position has a left shift with this parameter. Matching and hence bandwidth also affected with W.

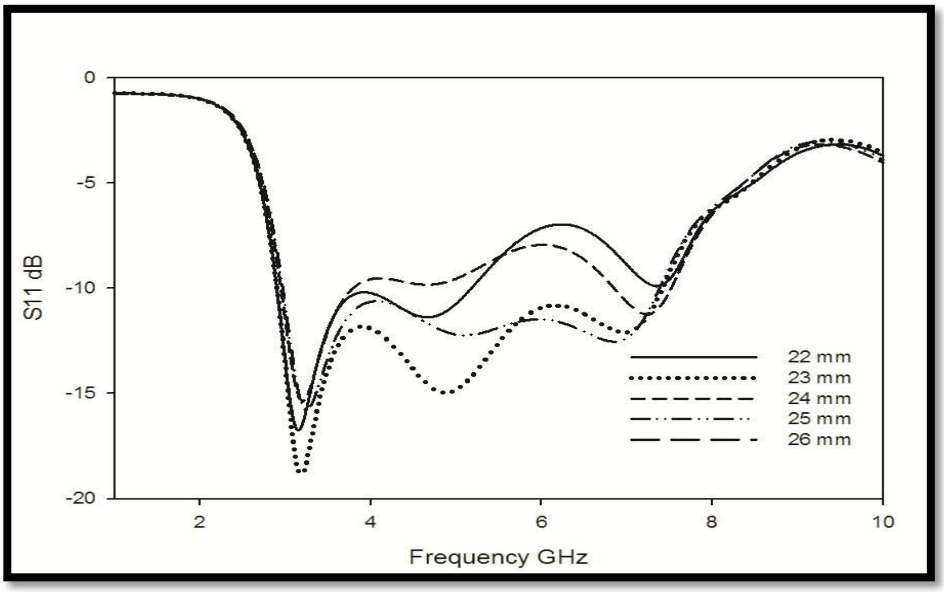

Fig.4. Effect of W on resonant frequencies

Variations in S11 of the antenna with slot length L1 is depicted in Fig.5. Here also the third resonance shows a considerable lowering with this parameter. Impedance matching at first and second resonance increases while that at third resonance decreases with L1 and thus bandwidth of the antenna decreases as L1 increases.

As next step, effect of slot width W1 is analysed and effect of this dimension on resonant frequencies is shown in Fig.6. First and third resonances get lower with W1. The interesting change is that of second resonance; it shows a higher shift with W1. This is due to the reduction in metallic part and thus the surface current path length with increase in W1.

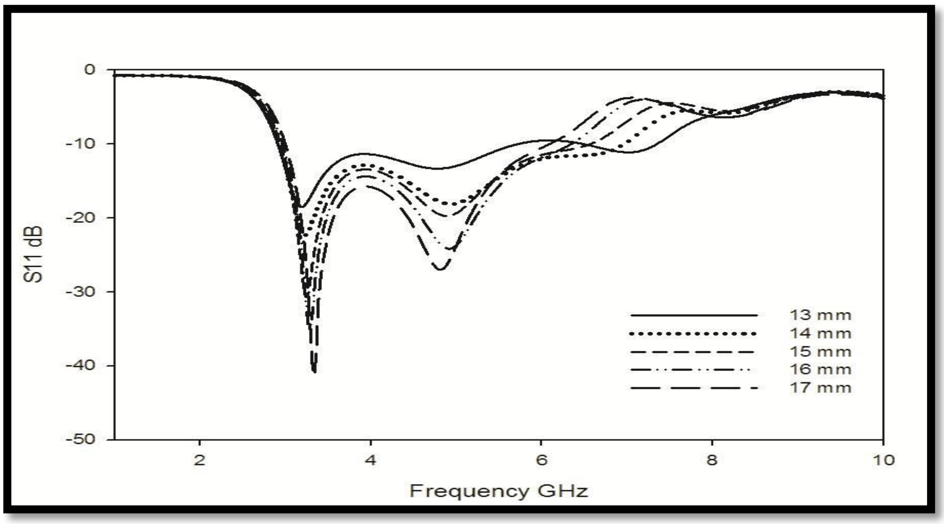

Fig.5. Effect of L1 on resonant frequencies

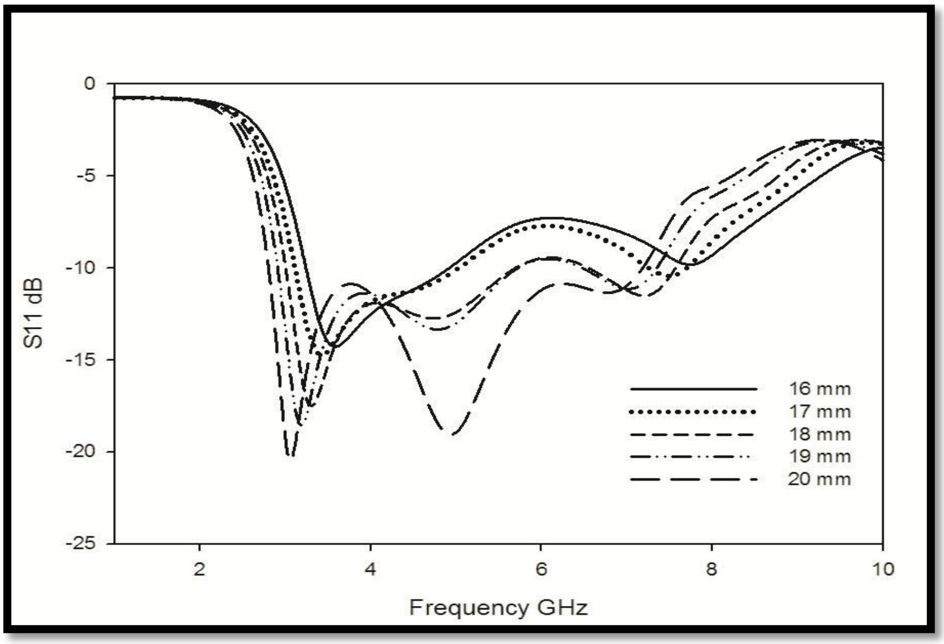

Fig.6. Effect of W1 on resonant frequencies

Effect of the radius of the quarter circle integrated at the corner of slot on resonant frequency is shown in Fig.7. At the absence of the corner quarter circular patch, matching is very poor and antenna does not have a wide band characteristics. On introducing this patch, matching at all the three resonances increases and antenna exhibits wide band characteristics. Resonance frequency positions are almost unaltered with this parameter.

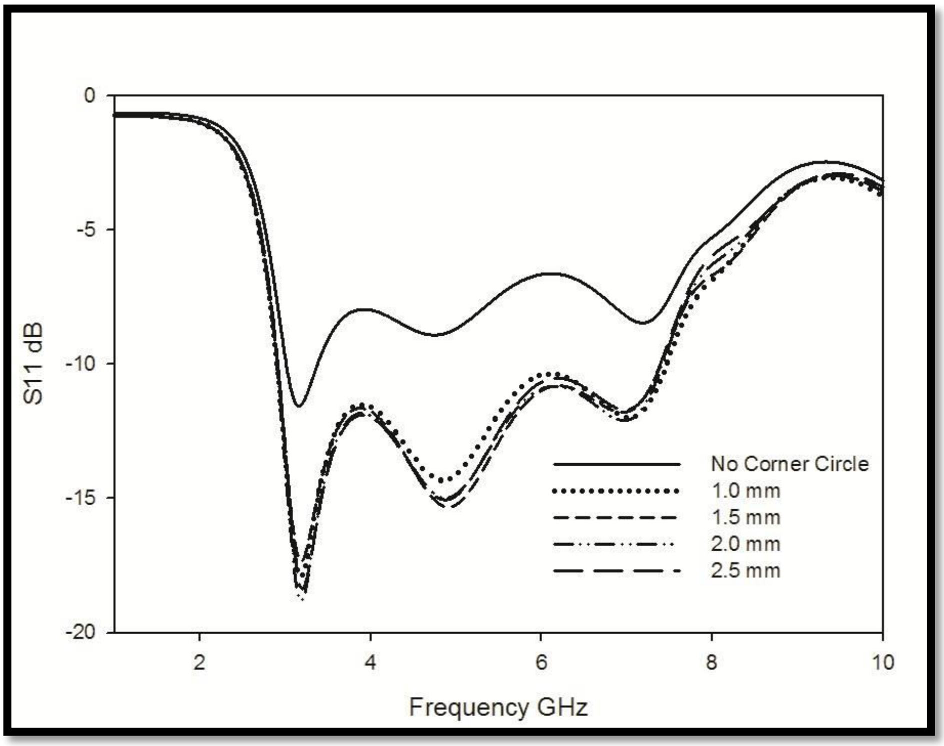

Fig.7. Effect of r on resonant frequencies

4. Results and Discussions

From the parametric analyses performed, optimized dimensions of a wide band antenna having maximum bandwidth characteristics with good impedance matching are attained and the parameters of the antenna are depicted in Table.1.

L	**W**	**L1**	**W1**
25 mm	23 mm	13 mm	19 mm
Ls	**Ws**	**Lg**	**s**
15 mm	3 mm	5 mm	1 mm
Poff	**r**	**h**	**ε**
4 mm	2 mm	1.6 mm	4.4

Table.1. Optimized Antenna Parameters

A prototype of the same is fabricated using photo lithographic technique on an FR4 substrate and tested using vector network analyser HP8510C. Experimental and simulated reflection characteristics of the antenna are graphed in Fig.8, which shows excellent correlation. Antenna offers a wide bandwidth of 4715 MHz starting from 2.875 GHz. It is also clear from the plot that antenna has three resonant frequencies at 3.256 GHz, 4.875 GHz and at 7.075GHz.

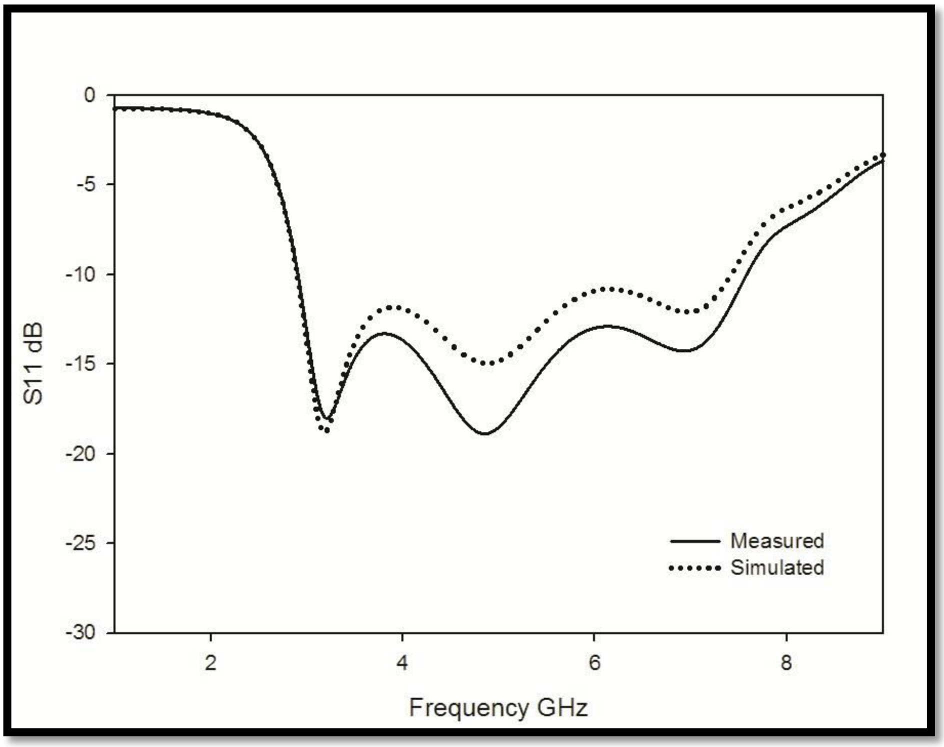

Fig.8. Measured and simulated S11 Curves

Radiation pattern is a 2D/3D pictorial representation of spatial distribution of far field radiation energy in the vicinity of antenna. Measured 2D radiation pattern of the antenna in both E and H principal planes at three resonances are depicted in Fig.9.At first two resonances, the E plane pattern attains a figure of eight shape while the H plane pattern is nearly isotropic. At third resonance, the radiation pattern is highly directive. In all the patterns beam maxima is oriented uniformly towards positive X direction and null is in

Y direction. The direction of Null also gives the polarization details such as linear polarization with E vector oriented in the direction of Y axis.

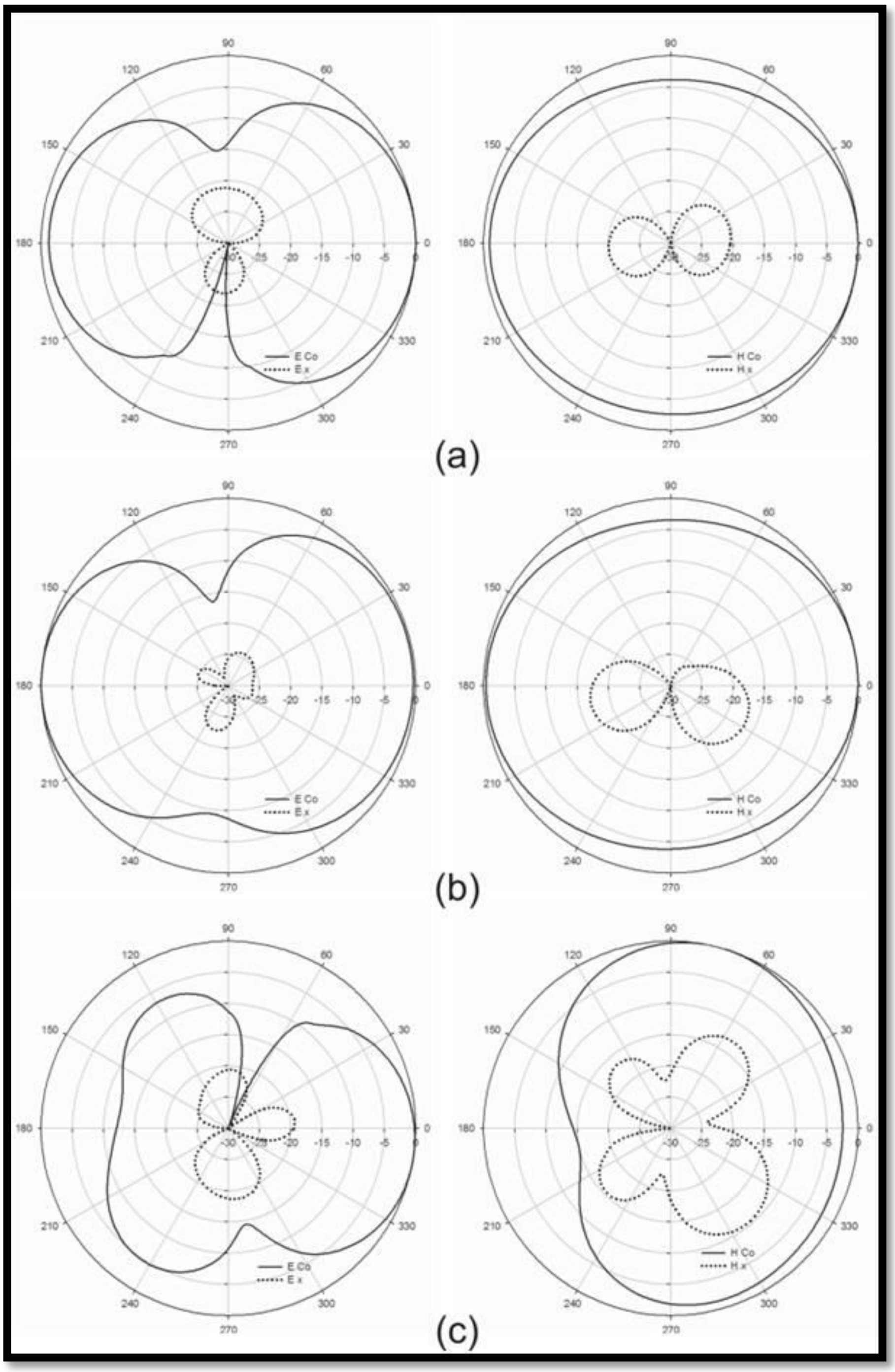

Fig.9. Measured Principle plane Radiation patterns at three resonances

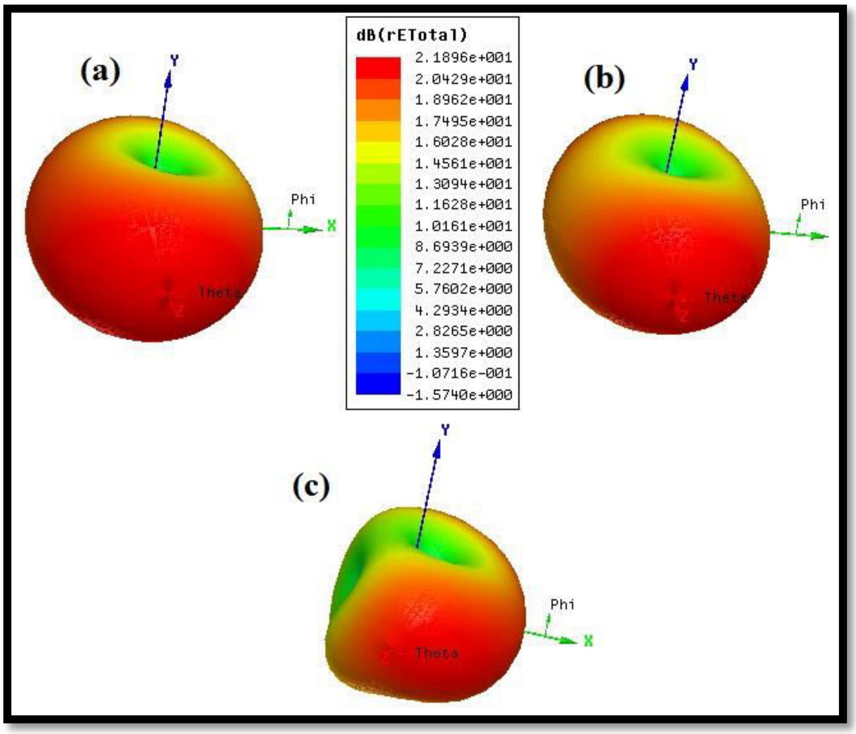

Fig.10. 3D Radiation patterns at three resonances

To validate and confirms the accuracy of the measured radiation pattern, 3D simulated pattern of the antenna also obtained and plotted, which is given in Fig.10. This figure confirms the validity of radiation and polarization parameters discussed in above session.

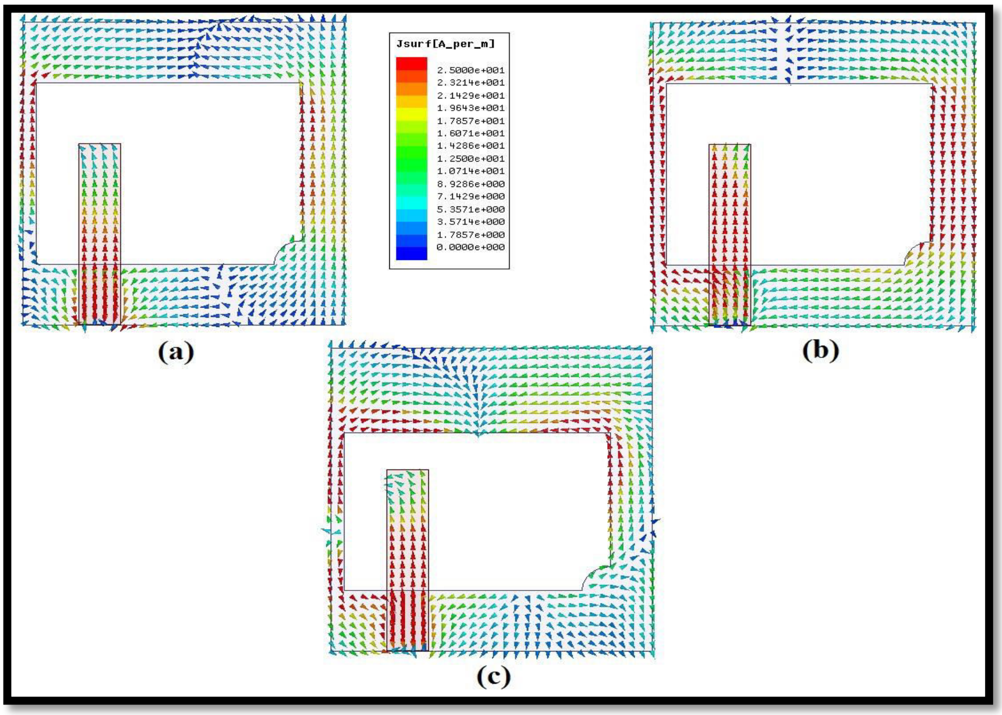

Fig.11. Vector Surface current Density plot

To reveal the mechanism of radiation and resonance creation of the structure, surface current of the antenna is analysed in three resonant frequencies. Simulated vector surface current of the antenna structure is given in Fig.11. An important speciality noted in this structure that, in all the three resonances, a linear and approximately quarter wavelength long current variation is present in the signal strip and thus the radiation efficiency of the structure will be very high. Surface current variation in the modified ground is varies with frequency. A multi folded current variations is found in higher two resonances.

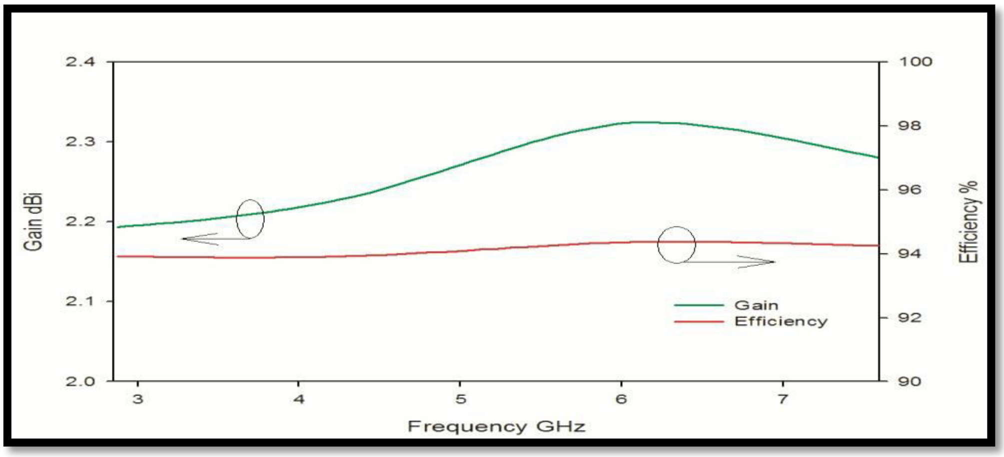

Fig.12. Measured Gain and efficiency Curve

Measured radiation efficiency and gain of the antenna compared to that of isotropic radiator is depicted in plot 12. From the green gain curve it is evident that antenna offers an average gain of 2.25 dBi with a peak value of 2.31 dBi at third resonance. This gain enhancement at higher resonance is due to the directional behaviour of antenna radiation pattern which can be inferred from Fig.9C and Fig.10C. Antenna offers nearly uniform radiation efficiency of the order of 94% in the whole operating bandwidth.

5. FDTD Modelling

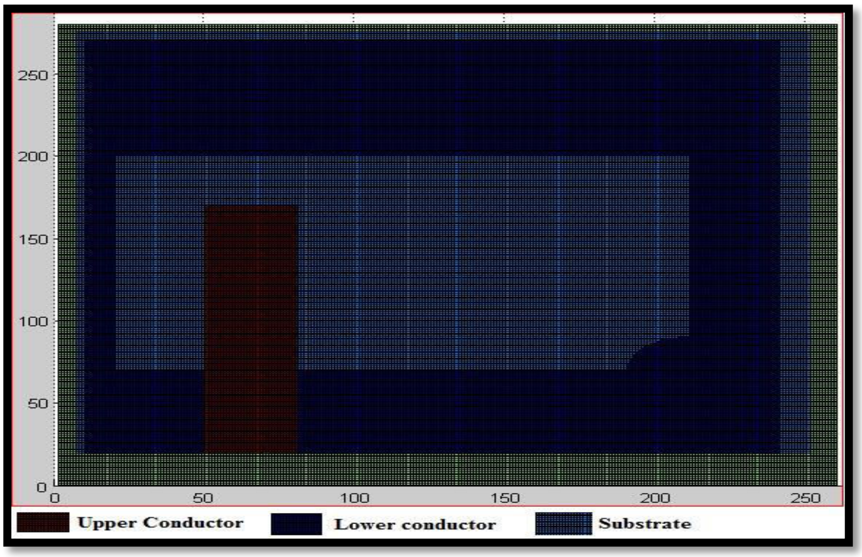

Fig.13. Structure used for FDTD calculations

Further theoretical science about the radiation mechanism behind the proposed wide band antenna can be obtained from Finite Difference Time Domain modelling and computations. An FDTD computation domain of the structure is developed with parameters specified in Table.2 and the results obtained are compared with simulated and measured results. Obtained computation domain of the structure is given in Fig.13.

ΔX	ΔY	ΔZ	Δt
0.05 mm	0.05 mm	0.05 mm	0.2 pS
No. of Steps	**Pulse**	**Pulse T**	**Pulse Delay**
15000	Gaussian 1^0	10 pS	100 pS

Table.2. Parameters of FDTD computation domain

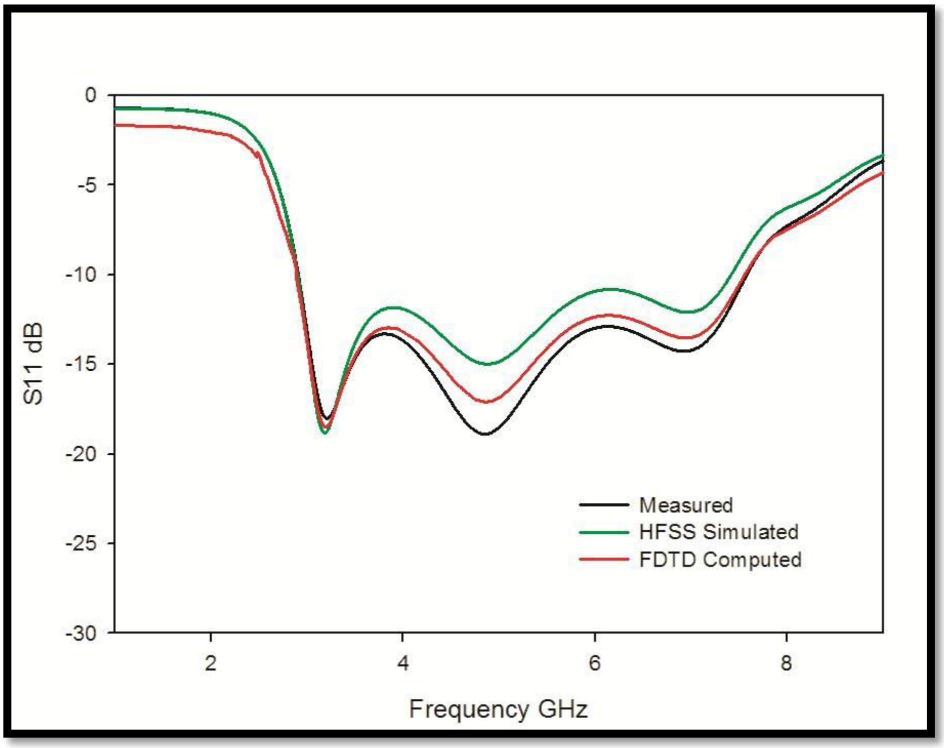

Fig.14. Measured, HFSS and FDTD S11- A comparison

From the computation, the reflection co efficient is obtained which is perfectly matched with the measured results and a comparison between measured, simulated and FDTD computed S11 is given in Fig.14, which confirms the validity of measurement and computations.

6. Conclusion

A slotted ground antenna with microstrip feed, having wide range of operating bandwidth ranging from 2.875 to 7.59 GHz capable of high data rate communication application is designed, developed and discussed. Antenna offers uniform radiation pattern, uniform polarization characteristics, flat and moderate gain and uniform and high radiation efficiency in the entire frequency range of operation. When fabricated on FR4, the overall volume of the structure is about 25 × 23 × 1.6 mm^3 which is compact when compared with other antennas. Parametric analysis of the structure and FDTD computation of the same are performed to analyse the antenna and the result obtained are discussed.

7. References

[1] Guoquan Zhang, Liming Xu, Aixin Chen and Donglin Su, "A microstrip-fed wide-band tapered slot antenna," 2008 International Conference on Microwave and Millimeter Wave Technology, 2008, pp. 1647-1650.

[2] M. Leib, M. Frei and W. Menzel, "A microstrip-fed ultra-wideband slot antenna," 2009 IEEE Antennas and Propagation Society International Symposium, 2009, pp. 1-4,

[3] N. Manshouri, A. Yazgan and M. Maleki, "A microstrip-fed ultra-wideband antenna with dual band-notch characteristics," 2016 39th International Conference on Telecommunications and Signal Processing (TSP), 2016, pp. 231-234.

[4] S. Singhal and A. K. Singh, "Microstrip fed star super wideband fractal antenna," 2016 Asia-Pacific Microwave Conference (APMC), 2016, pp. 1-3.

[5] C. L. Mak, K. M. Luk and K. F. Lee, "Wideband L-strip fed microstrip antenna," IEEE Antennas and Propagation Society International Symposium. 1999 Digest. Held in conjunction with: USNC/URSI National Radio Science Meeting (Cat. No.99CH37010), 1999, pp. 1216-1219 vol.2.

[6] L. C. Paul and H. K. Saha, "A Wideband Microstrip Line Feed Slotted Patch Antenna for 28 GHz 5G Applications," 2021 International Conference on Electronics, Communications and Information Technology (ICECIT), 2021, pp. 1-4.

[7] Jihak Jung, Woo young Choi and Jaehoon Choi, "A small wideband microstrip-fed monopole antenna," in IEEE Microwave and Wireless Components Letters, vol. 15, no. 10, pp. 703-705, Oct. 2005.

[8] A. A. Eldek, "Ultra wideband microstrip antenna for phased array applications," 2007 European Radar Conference, 2007, pp. 319-322.

[9] Lei Zhu, Rong Fu and Ke-Li Wu, "A novel broadband microstrip-fed wide slot antenna with double rejection zeros," in IEEE Antennas and Wireless Propagation Letters, vol. 2, pp. 194-196, 2003.

[10] A. A. Kadam, A. A. Deshmukh, K. P. Ray and S. B. Deshmukh, "Microstrip Fed Elliptical Slot UWB Antenna for Band Notch Response," 2019 IEEE Indian Conference on Antennas and Propogation (InCAP), 2019, pp. 1-4.

[11] Nasimuddin and Z. N. Chen, "Wideband Directional Microstrip Antennas fed by CPW-loop Combination," 2007 IEEE International Conference on Ultra-Wideband, 2007, pp. 700-702.

[12] Jen-Yea Jan, Chih-Yang Hsiang, Jia-Wei Su, Yuan-Tung Cheng and Wen-Shyang Chen, "Printed microstrip-line-fed wideband slot antenna with a hexagonal slot," 2005 IEEE Antennas and Propagation Society International Symposium, 2005, pp. 569-572 vol. 1B.

[13] X. L. Bao, M. J. Ammann and P. McEvoy, "Microstrip-Fed Wideband Circularly Polarized Printed Antenna," in IEEE Transactions on Antennas and Propagation, vol. 58, no. 10, pp. 3150-3156, Oct. 2010.

[14] Kyungho Chung, Jaemoung Kim and Jaehoon Choi, "Wideband microstrip-fed monopole antenna having frequency band-notch function," in IEEE Microwave and Wireless Components Letters, vol. 15, no. 11, pp. 766-768, Nov. 2005.

[15] R. S. Kushwaha, D. K. Srivastava, J. P. Saini and S. Dhupkariya, "Design of a Microstrip Line Fed Slotted Patch Antenna for Wideband Communications," 2012 Third International Conference on Computer and Communication Technology, 2012, pp. 178-182.

[16] A. H. Majeed, K. H. Sayidmarie, F. M. A. Abdussalam, R. A. Abd-Alhameed and A. Alhaddad, "A microstrip-fed pentagon patch monopole antenna for ultra wideband applications," 2015 Internet Technologies and Applications (ITA), 2015, pp. 452-456.

[17] B. -Y. Lee, W. -S. Chen and P. -Y. Chang, "A compact microstrip-line-fed slot antenna for wideband operation," 2009 Asia Pacific Microwave Conference, 2009, pp. 1884-1886.

[18] M. A. S. Al-zahrani, O. I. S. Al-qahtani, F. D. M. Al-sheheri, A. S. M. Qarhosh, A. M. Al-zahrani and M. S. Soliman, "Design and performance analysis of an ultra-wideband monopole microstrip patch antenna with enhanced bandwidth and single band-notched characteristics," 2017 Progress in Electromagnetics Research Symposium - Fall (PIERS - FALL), 2017, pp. 1488-1493.

[19] X. -P. Chen, N. -W. Liu and G. Fu, "A Compact Wideband Microstrip-Fed Patch Antenna Using a U-Shaped Parasitic Element," 2019 IEEE International Conference on Computational Electromagnetics (ICCEM), 2019, pp. 1-3.

[20] Y. Shen and C. L. Law, "A microstrip-fed quasi-spiral circularly polarized ultra-wideband antenna," 2011 IEEE International Symposium on Antennas and Propagation (APSURSI), 2011, pp. 1463-1466.