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Comparative Analysis of Triangular Grid with Ground Defected Microstrip Patch Antennas

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Abstract: The graded triangular microstrip patch antenna has been investigated for wireless systems for Ku band K band and Ka band application is analysed. The proposed antennas in this paper are of 31 X 20.5 mm of substrate FR4 of thickness 1.6 mm having dielectric constant of 4.4. These antennas are graded in patch in which the one antenna ground plane is defected and other one is without defected ground plane are considered and analysed for their performance. The antennas showed working on 7 frequencies of 15.4, 21.8, 23.6, 24.45, 25.5, 27.6, and 28.5 GHz(without ground plane defected) and 6 frequencies of 13.8, 19.8, 23.05, 26.9, 34.55, and 36.2 GHz which lies in Ku, K and Ka band respectively. The return loss obtained for both antennas are good precise for the 5G. The gain is also simulated with frequencies with a gain of around 1–96 dB and 1-13dB respectively for the antennas. The proposed antenna is designed, optimized and analysed with HFSS simulator.

Keywords: *Defected Ground Structure (DGS), Patch Antennas, Triangular Grid, Inset Line feeding, High Frequency*.

1. Introduction

The 5G generation wireless communication antenna has much more attention in recent years. Millimetre-wave range antenna is one of the vital components for the 5G communication because of its high-speed and data transmission rate. The wireless network system is speeding up in terms of data requirements [1]. A large number of researches focuses on this and several patch antennas are proposed [2]- [7]. A low-complexity slot antenna covering the frequency ranges 24.25-28.35 GHz band was proposed [3]. The notch antenna and an aperture-coupled antenna proposed to operate at mm Wave frequency for the 5G network [2]. The antennas in [6], the resonating frequency shifted up to 38.6 GHz and 70 GHz, currently, there are seldom antenna can cover the 28 GHz and 39 GHz band simultaneously. Presently, lower frequencies are highly crowded so a new frequency band in millimetre wave communication system is required [8]. The high frequency antenna can be used for upcoming communication systems that can be small in size with good gain [9]. Though many countries are already working on higher frequencies for 5G [10]. The 'World Radio Communication' which was held in November 2015, the upcoming broadband mobile communication band of above 24 GHz proposed [11].

Defected ground antenna is used in design for improving the bandwidth and gain [12]. DGS is being etched from ground plane that can cause to change in current distribution [13, 14]. These changes in current distribution affected the transmission line inductance and capacitance parameters [15].

2. Antenna Structure

The grid triangular in shape structures are shown in figure1 (a) as without defected ground and (b) with defected ground with line feed techniques are considered.

Table 1: Parameters of the grid triangular in shape antennas

S.no	Width of the patch				Length of the patch	Strip line feed		Ground defected		Ground without defected		Substrate (Materials glass)	
1	W1 (mm)	W2 (mm)	W3 (mm)	W4 (mm)	L (mm)	L1 (mm)	S1 (mm)	Width (mm)	Length (mm)	Width (mm)	Length (mm)	Width (mm)	Length (mm)
2	30	27	20	10	4.5	3	2	31	11	31	21	31	21

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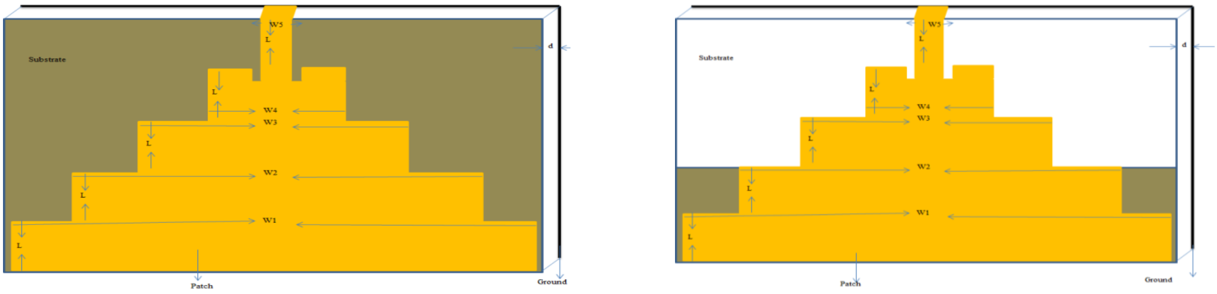

(a) (b)

Fig 1: Antenna structures (a) Without defected ground, (b) Defected ground antenna

3. Results and Discussion

The results of the antennas i.e. defected and without defected ground structures are discussed herewith as follows as:-

Return loss: The S_{11} i.e. the return loss for both antennas have multiband resonance frequencies achieved and the losses at all the resonance frequencies have reasonable in shown table2 for DGS antenna and without DGS antenna. The 7-resonance frequencies in multiple bands obtained for without DGS while 6-resonance frequencies in multiple bands obtained for DGS. The losses of without DGS -12.0208dB, -18.4642dB, -13.9206dB, -11.8451dB, -23.2913dB, -17.8361dB, -17.2938dB at the frequencies 15.4GHz, 21.8GHz, 23.6GHz, 24.45GHz, 25.5GHz, 27.6GHz, 28.5GHz respectively. The losses of DGS -31.3329dB, -16.8926dB, -16.6105dB, -20.9666dB, -14.0493dB,-20.2297dB, at the frequencies 13.8GHz, 19.8GHz, 23.05GHz, 26.9GHz, 34.55GHz, 36.2GHz, respectively. The analysis and comparison of these antennas are shown in table2from figure2.

Table 2: Return loss of without defected ground and with defected ground antenna

S. No.	Return loss of defected ground structure		Return loss without defected ground	
	Frequency in GHz	Return loss in dB	Frequency in GHz	Return loss in dB
m1	13.8	-31.3329	15.4	-12.0208
m2	19.8	-16.8926	21.8	-18.4642
m3	23.05	-16.6105	23.6	13.9206
m4	26.9	-20.9666	24.45	-11.8451
m5	34.55	-14.0493	25.5	23.2913
m6	36.2	-20.2297	27.6	-17.8361
m7	----	----	28.5	-17.2938

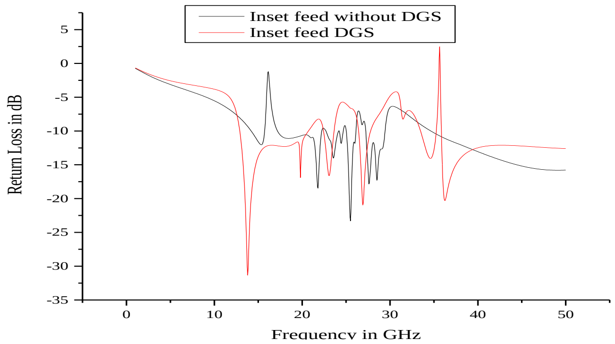

Fig 2: Return loss vs frequency for DGS and without DGS Line feed technique

Gain: The gain of antenna has 3.8398dB, 1.0877dB, 0.7327dB, 11.2154dB, 3.2109dB, 19.4861dB, and 13.6638dB at the frequencies 15.4GHz, 21.8GHz, 23.6GHz, 24.45GHz, 25.5GHz, 27.6GHz, 28.5GHz respectively. And for DGS antenna has 0.1584dB, 10.5324dB, 9.9079dB, 13.3193dB, 2.6715dB, 4.172dB, at the frequencies 13.8GHz, 19.8GHz, 20.05GHz, 26.9GHz, 34.55GHz, 36.2GHz, respectively. The analysis and comparison of the antennas are shown in table3for figure3.

Table 3: Gain defected ground antenna and without defected ground antenna

S. No.	Gain defected ground Antenna		Gain without defected ground Antenna	
	Frequency in GHz	Gain in dB	Frequency in GHz	Gain in dB
m1	13.8	0.1655	15.4	3.8398
m2	19.8	10.5324	21.8	1.0877
m3	23.05	9.9079	23.6	0.7327
m4	26.9	13.3193	24.45	11.2154
m5	34.55	2.6715	25.5	3.2109
m6	36.2	4.172	27.6	19.4861
m7	----		28.5	13.6638

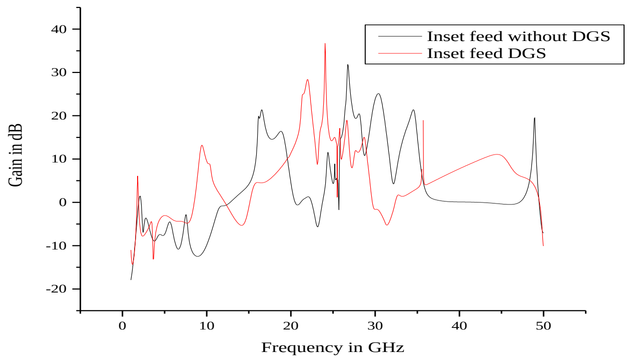

Fig 3: Gain vs frequency; without DGS antenna and DGS antenna

Directivity: The directivity of the antenna has 0.3123dB, 0.4539dB, 0.0155dB, 1.9183dB, 3.3229dB, 5.3087dB, 4.5603dB at the resonance frequencies 15.4GHz, 21.8GHz, 23.6GHz, 24.45GHz, 25.5GHz, 27.6GHz, 28.5GHz respectively. And DGS antenna has 0.0584dB, 0.3237dB, 0.1002dB, 1.9612dB, 3.2098dB, 4.7604dB, at the resonance frequencies 13.8GHz, 19.8GHz, 23.05GHz, 26.9GHz, 34.55GHz, 36.2GHz, respectively, the analyzed and compared results of the antennas are shown in table4 from the figure4.

Table 4: Directivity of inset feed defected ground antenna and without defected ground antenna

S. No.	Inset feed DGS		Inset feed without DGS	
	Frequency in GHz	**Directivity in dB**	**Frequency in GHz**	**Directivity in dB**
m1	13.8	-6.6507	15.4	0.3123
m2	19.8	-0.6057	21.8	0.4539
m3	23.05	-2.7834	23.6	0.0155
m4	26.9	1.9612	24.45	1.9183
m5	34.55	3.2098	25.5	3.3229
m6	36.2	4.7604	27.6	5.3087
m7	----		28.5	4.5603

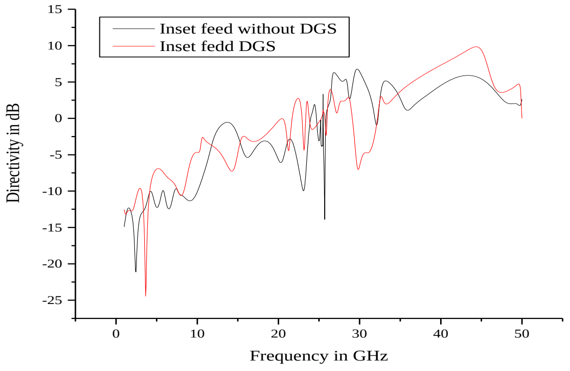

Fig 4: Directivity vs frequency; for the defected ground structure antenna and without DGS antenna

VSWR: The vswr of the antenna has 4.4478dB, 2.0831dB, 3.5464dB, 1.1911dB, 2.241dB, 4.6121dB, 4.7607dB at the resonanance frequencies 15.4GHz, 21.8GHz, 23.6GHz, 25.5GHz, 27.6GHz, 24.4GHz, 26.05GHz respectively. And DGS antenna has 0.4713dB, 2.5853dB, 1.5584dB, 3.4928dB, 1.6972dB, at the resonanance frequencies 13.8GHz, 19.8GHz, 23.05GHz, 26.9GHz, 34.55GHz, 36.2GHz, respectively, the analyze and compared result of the antennas are shown in table5 from figure5.

Table5: VSWR of inset feed without defected ground antenna and inset feed DGS antenna

S. No.	Inset feed DGS		Inset feed without DGS	
	Frequency in GHz	**VSWR in dB**	**Frequency in GHz**	**VSWR in dB**
m1	13.8	0.4713	15.4	4.4478
m2	19.8	2.5015	21.8	2.0831
m3	23.05	2.5853	23.6	3.5464
m4	26.9	1.5584	25.5	1.1911
m5	34.55	3.4928	27.6	2.241
m6	36.2	1.6972	24.4	4.6121
m7	----	----	26.05	4.7607

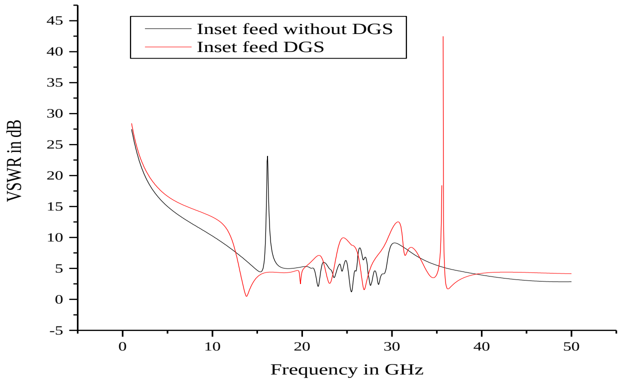

Fig 5: VSWR vs frequency; for DGS antenna and without DGS antenna"

Axial Ratio: The axial ratios of antenna has 44.1357dB, 11.6608dB, 10.8203dB, 16.8796dB, 7.4459dB, 10.4562dB, 10.7792dB at the resonant frequencies 15.4GHz, 21.8GHz, 23.6GHz, 24.45GHz, 25.5GHz, 27.6GHz, 28.5GHz respectively. And the DGS antenna has 4.8839dB, 13.5903dB, 7.7383dB, 5.5673dB, 34.5566dB, 19.1040dB, at the resonance frequencies 13.8GHz, 19.8GHz, 23.05GHz, 26.9GHz, 34.55GHz, 36.2GHz, respectively, the analyzed and compared results of the antennas are shown in table6 from figure6.

Table 6: Axial ratio of inset feed DGS antenna and inset feed without DGS antenna

S. No.	Inset feed DGS		Inset feed without DGS	
	Frequency in GHz	**Axial ratio in dB**	**Frequency in GHz**	**Axial ratio in dB**
m1	13.8	4.8839	15.4	44.1357
m2	19.8	13.5903	21.8	11.6608
m3	23.05	7.7383	23.6	10.8203
m4	26.9	5.5673	25.5	16.8796
m5	34.55	33.5566	27.6	7.4459
m6	36.2	19.1040	24.4	10.4562
m7	----	----	26.05	10.7792

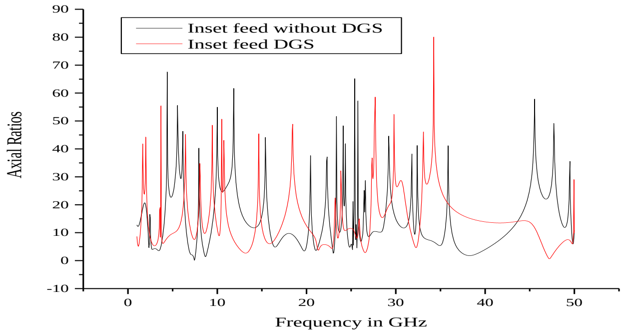

Fig 6: Axial ratio vs frequency; DGS antenna and without DGS antenna

Impedance: The impedance Z_{11} of the antenna has 33.2418dB, 33.3821dB, 36.9828dB, 29.7966dB, 33.3759dB, 32.1362dB, 34.5195dB at the resonance frequencies 15.4GHz, 21.8GHz, 23.6GHz, 24.45GHz, 25.5GHz, 27.6GHz, and 28.5 GHz respectively. And DGS antenna has 37.0976dB, 29.6717dB, 38.7901dB, 38.1827dB, 39.7000dB, 38.8529dB at the resonance frequencies 13.8GHz, 19.8GHz, 23.05GHz, 26.9GHz, 34.55GHz, 36.2GHz respectively, analysed and compared results are shown in table7 from the figure7

Table 7: Impedance of inset feed antenna and line feed antenna

S. No.	Inset feed DGS		Inset feed without DGS	
	Frequency in GHz	**Impedance in dB**	**Frequency in GHz**	**Impedance in dB**
m1	13.8	37.0976	15.4	33.2418
m2	19.8	29.6717	21.8	33.3821
m3	23.05	38.7901	23.6	36.9828
m4	26.9	38.1827	24.45	29.7966
m5	34.55	39.7000	25.5	33.3759
m6	36.2	38.8529	27.6	32.1362
m7	----	---	28.5	34.5195

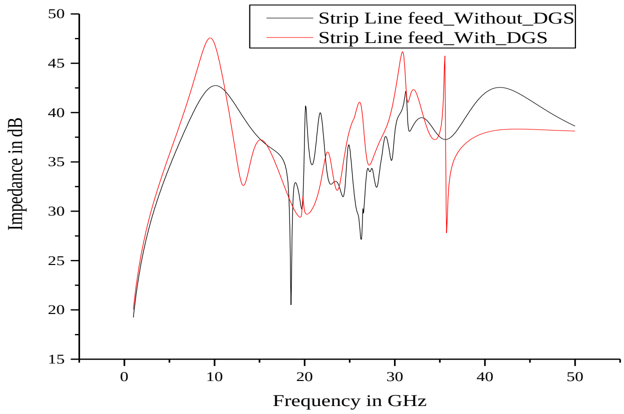

Fig 7: Impedance vs frequency; DGS antenna and without DGS antenna

4. Conclusion

The inset feed without DGS antenna has 7 resonance frequencies 15.4GHz, 21.8GHz, 23.6GHz, 24.45GHz, 25.5GHz, 27.6GHz, 28.5GHz which are used in the Ku, K and Ka band application , and with DGS line feed antenna has 6- resonance frequencies 13.8GHz, 19.8GHz, 23.05GHz, 26.9GHz, 34.55GHz, 36.2GHz, The DGS and without DGS antenna have good overall results i.e. return losses gains directivities, vswr, axial ratios and impedances (Z_{11}).

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