Design of Rectangular Patch Array Antennas for Future 5G LTE Applications

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Abstract- The main aim of this paper is to design and simulation of rectangular patch antenna arrays with micro strip and coaxial feeding techniques and generate resonant frequency at 28GHz for future 5G applications. Here our objective is to design a four element antenna array i.e. 4*1 and 2*2 array with large bandwidth i.e. higher than 1GHz and with maximum radiation gain and less return losses. These antenna arrays are designed over a Rogers RT/Duroid 5880 substrate with dielectric constant 2.2, thickness of 0.508 and loss tangent of 0.0009.The optimum design parameters of the antenna arrays are chose to get the compact design and also best possible characteristics such as large bandwidth ,high gain, low return losses. The simulation results shows that 2*2 antenna array fed by coaxial line is better than 4*1 antenna array fed by micro strip line. Gain of 2*2 and 4*1 antenna array is 12.56db and 10.81db.bandwidth of 2*2 and 4*1 antenna array is 0.9GHz and 1GHz.Return losses of 2*2 and 4*1 antenna array is -49.56db and -12.52db.

Keywords- patch antenna, micro strip line feed, coaxial feed, 5G.

I. INTRODUCTION

The standardization of 5G is being developed with a first deployment planned for the moment in 2020.4G cannot meet current requirements such as congestion or the reduction of energy consumption. That is why the world is focuses on 5G.

The 5G which will probably still see a large increase in data volumes exchanged .And it uses a millimeter bands. Millimeter band is a band of spectrum from 26GHz to 300GHz.It is also known as extremely high frequency (EHF) or veryhigh frequency(VHF).It is a undeveloped band of spectrum that can be used in a broad range of products services like high speed, point to point WLANS etc. In 5G the allocation of data rate is up to 10Gbps.As it uses low propagation capacity with implementation of small cell radio transmitter. It is used to identify several trends of 5G specifications.

The improvement of data speed and also latency can be increased by using 5G.The specifications of 5G should have to work in real time such as autonomous vehicles, remote surgery and IoT applications like MIMO structures, smart cities, smart grids, telemedicine and machine to machine communication.

Now-a-days the wireless technology is rapidly expanding due to the number of users increased in terms of internet usage. Modern wireless communication system should require low profile, high gain and simple structure antennas. Normally the micro strip patch antenna can combined all these requirements to the simplicity and compatibility with PCB technology .The specification of micro strip patch antenna are the multiband properties.

The antenna achieves nearly omni directional pattern. It has numerous advantages for these reasons many students have been made to improve the performance of antenna patch. By using multiple number of slots in ground plane has enhanced the bandwidth. another way to improve the bandwidth efficiency of patch antenna is to reduce the dielectric constant of the substrate. The return losses can be reduced by decreasing the thickness of the substrate.

II. PATCH ANTENNA THEORY AND DESIGN:

Here we design microstrip patch antenna fed by microstrip line feed and co-axial feed.fig1 shows basic structure of microstrip patch antenna.In this radiating patch,dielectric substrate and ground plane are present.

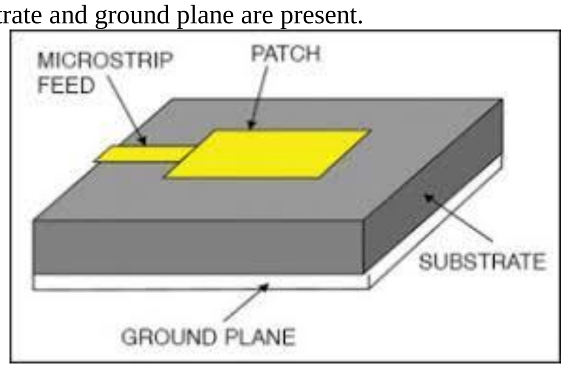

Fig.1: Rectangular patch antenna

DESIGNING EQUATIONS:

$$W = \frac{c}{2f_0\sqrt{\frac{\varepsilon_r+1}{2}}}$$

$$L = L_{eff} - 2\Delta L$$

$$L_{eff} = \frac{c}{2f_0\sqrt{\varepsilon_{eff}}}$$

$$\varepsilon_{eff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[1+\frac{12h}{W}\right]^{-1/2}$$

$$\Delta L = 0.412\square \frac{\left(\varepsilon_{eff+}0.3\right)\left(\frac{W}{\square}+0.264\right)}{\left(\varepsilon_{eff}-0.258\right)\left(\frac{W}{\square}+0.8\right)}$$

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$$L_{sub} = 6\square + L$$

$$W_{sub} = 6\square + W$$

Where W is the width of the antenna and L is the length of the antenna

f_0 is the resonant frequency of the antenna

ε_r is the dielectric constant of the substrate

ε_{eff} is the effective dielectric constant .We must be calculated effective dielectric constant because the radiation done through the air and dielectric substrate. The dielectric constant of the air and substrate are different

Where 'h' is the substrate thickness.

L_{eff} is the effective length of the patch..We must calculate effective length because the radiation done through the width of the patch.So, the length of the patch changes.

where L_{sub} is the length of the substrate.

W_{sub} is the width of the substrste.

III. DESIGN OF ANTENNA

In the designing of antenna we use Rogers RT/Duroid 5880 as substrate with a dielectric constant 2.2 and a loss of tangent 0.0009.This substrate has low dielectrictic loss tangent.Due tothis we can enhance the antenna gain and maximum radiation can be improved.

TABLE 1: THEORITICAL DIMENSIONS OF RECTANGULAR PATCH ANTENNA.

parameter	value
h(mm)	0.508
W(mm)	4.23
L(mm)	3.28
ΔL	0.26
ε_{eff}	1.98
L_{sub}	6.3
W_{sub}	7.28

In the microstrip line feed to achieve 50 impedance,we should calculate W_f(line width).This parameter depends on the thickness of the substrate,whereas in the co-axial feed we should calculate inner conductor radius(r_{in}) and outer the conductor radius(r_{out}) to achieve the characteristic impedance 50Ω.

TABLE 2:FEEDING PARAMETERS:

parameter	h(mm)	r_{in}	$(r_{out}$	W_f
value	0.508	0.51	1.173	1.62

IV. SIMULATION RESULTS

Here we will show the simulation results of different rectangular patch antennas by using different feeding techniques using ANSYS HFSS CAD tool(High Frequency Electromagnetic Field Simulation).

A)SINGLE PATCH ANTENNA: The dimensions of the single rectangular patch antenna were optimised for the co-axial feed and microstrip feed to obtain the resonant frequency 28GHZ.When thickness(h) of the substrate is increased then the the band width of the antenna is improved.Here our main aim is to obtain return losses lower than -20db.

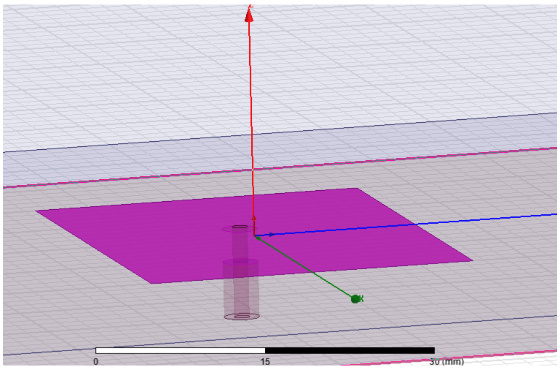

Fig.2: Geometry of rectangular patch antenna with co-axial feed.

For a rectangular patch antenna with microstrip line feed ,the gap parameter y1 was adjusted to obtain minimum return losses at the resonant frequency 28GHZ.For achieving minimum return losses we choose the length of the patch L=3.52mm and y1(gap)=1.1mm.

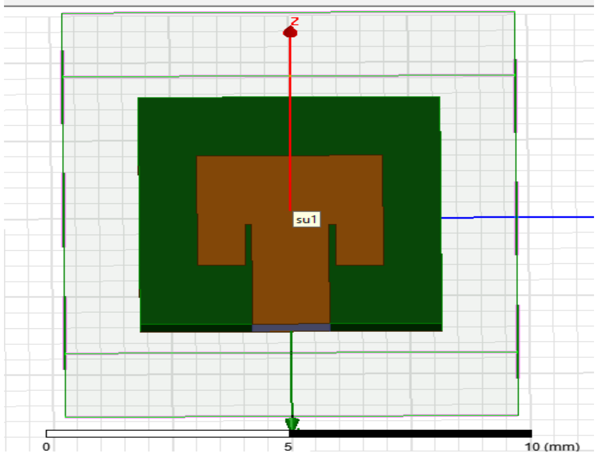

Fig.3:Geometry of rectangular patch antenna with microstrip line feed.

The simulated return losses for the patch antenna with microstrip line feed is shown in the fig4.

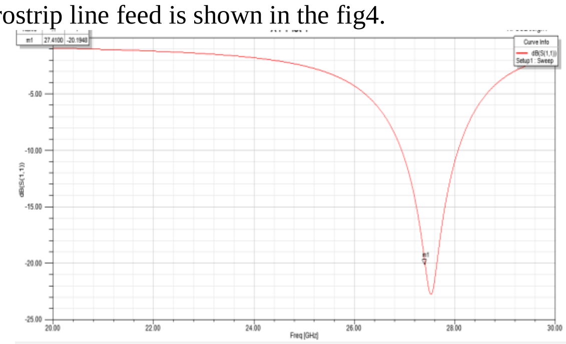

Fig.4:Simulated resurn losses(S11) of rectangular patch antenna with microstrip feed.

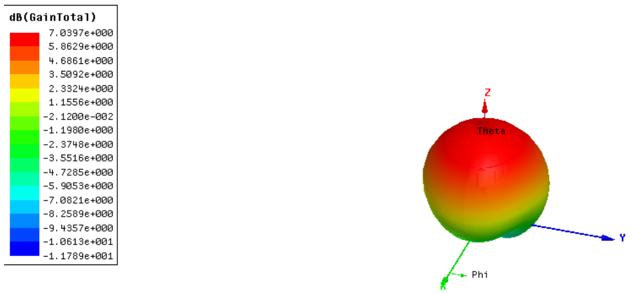

Fig.5: Simulated gain 3D plot of rectangular patch antenna with microstrip line feed.

B)Rectangular patch array antenna:

By using single antenna we cannot achieve high gain.So by using multiple antennas we can achieve high gain and bandwidth and also we can achieve minimum return losses.

1) Two-element antenna array design:

Here up to now we have designed the single patch antenna.So it doesnot exceed more than 7db.For the system of 5g, 7db gain is very small value.For this reason we should extend the single antenna as an array antenna.For the design of array antenna we should use the configuration of T-junction.

The T-junction means the junction which is in T-shaped that in a particular slot at which on eslot joins another at right angles without crossing it.By using this configuration we can design a 2 element antenna array with different calculation methods and we can increase a 3% of gain rather than the single antenna and also it allows good impedance matching over a frequency band.

FIG 6:T-Junction configuration:

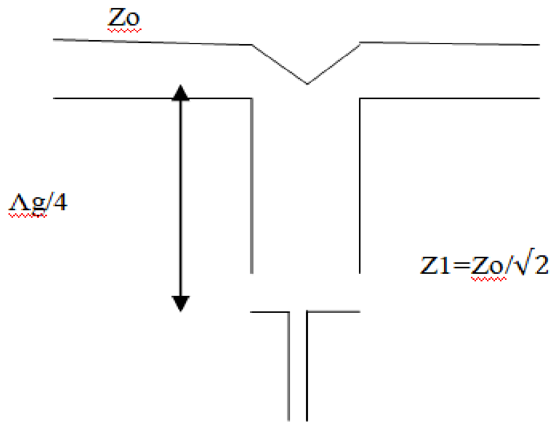

Fig.6:T-Junction configuration.

For designing two element antenna array,the spacing between the antennas with a distance of 7.4mm.The distance d was reduced to achieve the maximum gain.The simulated gain,return losses,gain 2D pattern,fed by microstrip line feed were shown in the below figure.

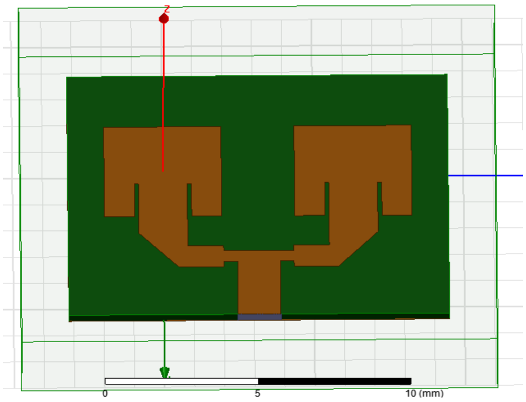

Fig.7:Geometry of the 2*1 rectangular patch array antenna.

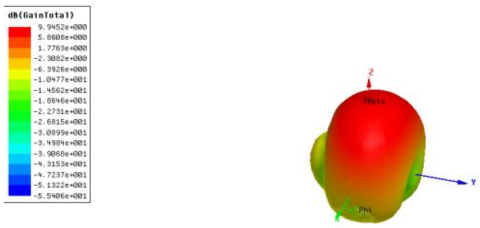

Fig.8:Simulated 3D gain plot of 2*1 patch array antenna.

When the number of antenna elements is doubled then the gain is increased by 3db.The gain of two elements is equal to 9.94db.

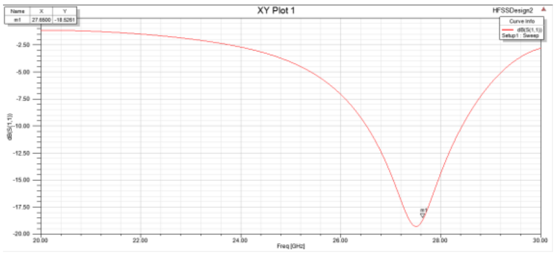

Fig.9:Simulated return losses for the 2*1 patch array antenna .

2)4*1 antenna array with microstrip line feed:

The radiating elements are mounted on the surface of the substrate material with a thickness of 0.508mm and a relative permitivity of 2.22.We should consider the spacing between the elements of the array,because it directly effects the gain and radiation pattern of the antenna.We can achieve the maximum gain when the spacing is between 0.4λo and 0.9 λo.If the two elements are near to each other,coupling phenomena reduces the gain value and when they are too far apart,side lobes formed and automatically the gain parameter is reduced.

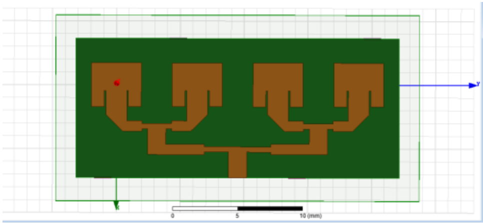

Fig.10:Geometry of the 4*1 rectangular patch array antenna.

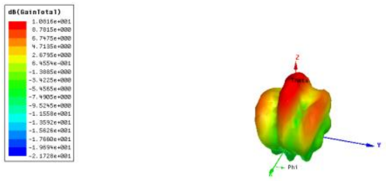

Fig.11: Simulted 3D gain plot of 4*1 rectangular patch array antenna.

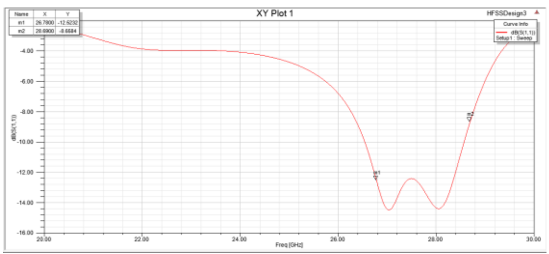

Fig.12: Simulated return losses of 4*1 rectangular patch array antenna.

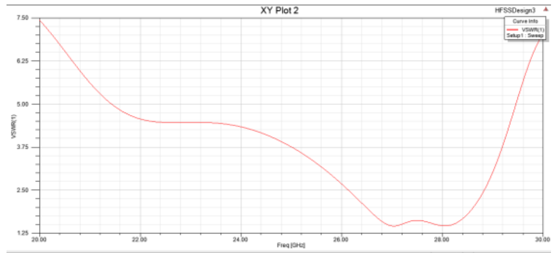

Fig.13:Simulated VSWR of 4*1 rectangular patch array antenna.

3)2*2 antenna array with co-axial feed:

The design of 2*2 rectangular patch array antenna is shown in the fig14.The radiated element are feeding with microstrip line and the antenna array is feeding with co-axial line.The gap between the radiating elements are 7mm and 7.2mm.

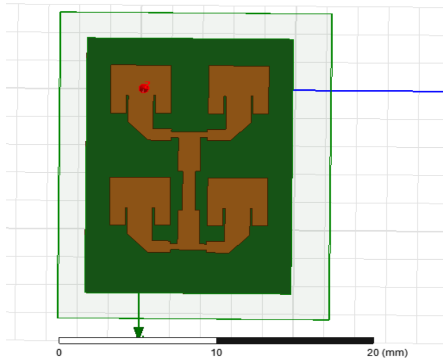

Fig.14: Geometry of 2*2 rectangular patch array antenna fed by coax.

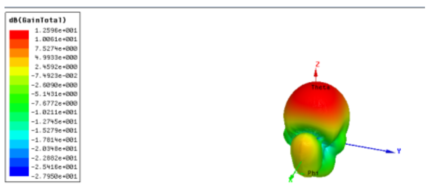

Fig.15: Simulated gain 3D plot of 2*2 rectangular patch array antenna fed by coax

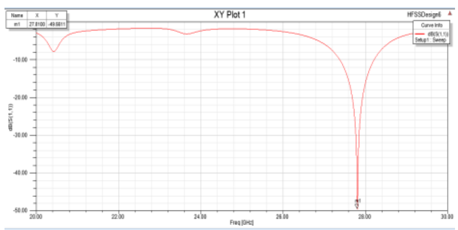

Fig.16: Simulated return losses of 2*2 rectangular patch array antenna fed by coax

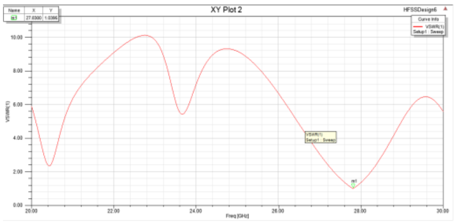

Fig.17: Simulated VSWR OF 2*2 rectangular patch array antenna fed by coax.

When we compare among the 3 structures we conclude that the gain is given by 2*2 rectangular patch array antenna(gain=12.56db)compared with the gain of 2*1 and 4*1 rectangular patch array antenna which is equal to 9.94db and 10.81db.By comparing 3 structures of antenna array we noticed that the bandwidth is given by 4*1 rectangular patch array antenna(bandwidth=1GHZ) more efficient than the bandwidth of 2*1,2*2 rectangular patch array antenna.

TABLE III. 1*1,2*1,2*2 and 4*1 patch antenna array dimensions.

Parameter	Single patch antenna	2*1 patch array antenna	4*1 patch array antenna	2*2 patch array antenna
h(mm)	0.508	0.508	0.508	0.508
W(mm)	4.23	3.7	4.23	3.92
L(mm)	3.28	3.4	3.28	3.26
L_{sub}(mm)	6.3	14	21.6	22.8
W_{sub}(mm)	7.28	10	31.6	19.2
d(mm)	-	7.4	7.4	-
d 2(mm)	-	-	5.5	-
d'(mm)	-	-	-	7
d 1(mm)	-	-	-	7.2

TABLE IV:Comparision between 1*1,2*1,4*1 and 2*2 rectangular patch array antenna simulation performances.

Parameter	1*1 rectangular patch array antenna	2*1 rectangular patch array antenna	4*1 rectangular patch array antenna	2*2 rectangular patch array antenna
Minimum return losses(db)	-20.19	-18.32	-12.52	-49.56
Gain(db)	7.07	9.94	10.81	12.56
VSWR	1.2	1.25	3	1.03

By observing the above results we conclude that 2*2 rectangular patch array antenna with co-axial feed is better than the 4*1 rectangular patch array antenna with microstrip line feed in terms of return losses,gain and VSWR.

FABRICATED 4*1 RECTANGULAR PATCH ARRAY ANTENNA:

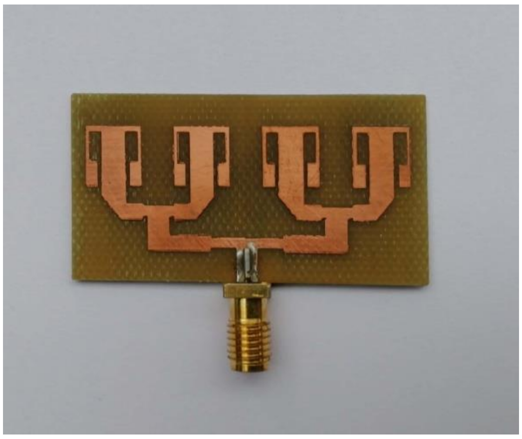
Fig.18: Fabricated 4*1 rectangular patch array antenna.

V. CONCLUSION

The design of 2*1 and 4*1 rectangular patch array antenna fed by micro strip line and coaxial feed were successfully designed and analyzed by using HFSS .The performance parameters for the 4*1 rectangular patch array antenna were optimized with return loss -12.52,gain 10.81db,bandwidth 1 GHz. For 2*2 rectangular patch array antenna return losses -49.56db ,gain 12.56 db and bandwidth 0.9GHz.

In the further work, antenna array of n elements and reconfigurable antenna for the control of the radiation pattern by using the technique of hybrid beam forming will be investigated.

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