DESIGN OF MID-BAND FREQUENCY PATCH ANTENNA FOR 5G APPLICATIONS

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Abstract – *The purpose of the paper is to investigate the design of rectangular patch antenna array fed by microstrip line at 5.2GHz for 5G applications. Our objective is to design a two element antenna array with bandwidth of about 1GHz and maximum radiation gain. The performance of rectangular 2*1 patch antenna array designed on FR-4 was analyzed. We obtain for topology of 2*1 rectangular array patch array antenna a bandwidth of 1 GHz respectively with almost similar gain of the order of 6 dBi.*

Keywords - component; 5G applications; microstrip line; patch array antenna

1. INTRODUCTION

4G has reached maturity after being deployed around 2010.No major changes in the network structure have been made while the mobile communications market is expanding. 4G cannot meet current requirements such as spectral congestion or the reduction of energy consumption. That is why the world focuses on the 5G. The standardization of 5G is being developed, with a first deployment planned for the moment in 2020[1]. 5G, which will probably still see a large increase in data volumes exchanged, and which will use millimeter bands, with low propagation capacity, will probably require the generalization of the implementation of small-cell radio transmitter [2].

Modern wireless communication systems require low profile, high gain, and simple structure antennas. Microstrip antennas meet some requirements due to their simplicity and compatibility with printed circuit technology [4].

However their limitations are specifically narrow frequency band. For these reasons, many studies have been made to improve the performances of the antenna patch. Bandwidth can be enhanced by using multiple numbers of slots in ground plane [5]. Another way to improve the bandwidth and efficiency of the conventional patch antenna is to reduce the substrate dielectric constant [6] [7]. It is also known that the antenna return loss can be considerably increased by searching the optimal position in case of coaxial feed or designing progressive matching network in case of microstrip line feed [9].

It deals with how to improve the performances of a rectangular patch antenna and a rectangular patch antenna array at 5.2 GHz for WLAN, WiMax and Wi-Fi applications. First, we will describe the design of the rectangular patch antenna at 5.2 GHz which is necessary to calculate radiation parameters of the antenna (return loss, radiation pattern, gain).Finally we will show the simulation results of the return loss for the optimal position of the microstrip line feed for the rectangular patch antenna array.

1.1 ATENNA THEORY

The components of a microstrip patch antenna are a conducting rectangular patch and a ground plane separated by a dielectric substrate given by fig. 1.

The width W and length L of the antenna are calculated using the equations from (1) to (4) [9].

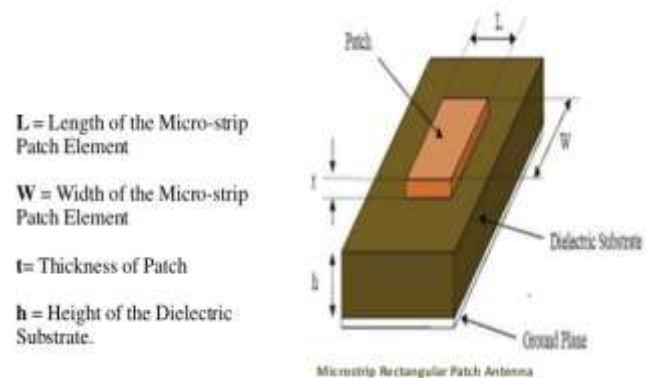$$W = \frac{c}{2 f_0 \sqrt{\dfrac{\varepsilon_r + 1}{2}}}$$

L = Length of the Micro-strip Patch Element

W = Width of the Micro-strip Patch Element

t = Thickness of Patch

h = Height of the Dielectric Substrate.

Figure 1. Rectangular patch antenna

Where f_0 is the resonant frequency and ε_r is the dielectric constant.

The radiations pass through air and some through the substrate to reach the ground. The air and the substrate have different dielectric constant values, therefore an effective dielectric constant (ε_{eff}) has to be considered. It is calculated using the equation (2) [9].

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

Where h is the thickness of the substrate.

The length of the patch is calculated using equation(3)[9].

$$L = \frac{c}{2 f_0 \sqrt{\varepsilon_{eff}}} - 2\Delta L \qquad (3)$$

Electrically the size of the antenna is increased by an amount of ΔL due to fringing.The increased length is given using the equation (4).

$$\Delta L = 0.412h \frac{(\varepsilon_{eff} + 0.3)(\frac{W}{h} + 0.264)}{(\varepsilon_{eff} - 0.258)(\frac{W}{h} + 0.8)} \qquad (4)$$

The minimum length (*Lsub*) and the minimum width (*Wsub*) of the substrate are calculated using equation (5) and) [9].

$$Lsub = 6h + L \qquad (5)$$

$$Wsub = 6h + W \qquad (6)$$

The theoretical parameters of the single rectangular patch were optimized for the microstrip feed to meet the requirement of the resonant frequency at 5.2GHz. While the design process of the patch antenna was carried out, we found that when h is increased the antenna bandwidth is improved. So, we have considered the standard thickness of 1.6mm as the height of the patch and the ground plane. Our objective is to reach a return loss lower than -10 dB.
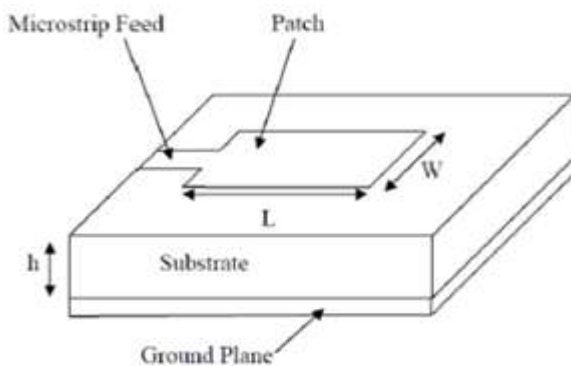

Figure 2. Patch with microstrip line feed

2. EXISTING SYSTEM

The rectangular patch antenna containing two radiating elements with coaxial feeding technique, designed with

Rogers RT/Duroid 5880, to operate at 28GHz frequency does not have a complete planar structure and this feeding method makes the design prone to narrow bandwidth and in case of thicker substrates, the increased probe length makes the input impedance more inductive leading to matching problems. It also may have some asymmetries due to which higher order modes are generated.

3. PROPOSED SYSTEM

Due to the drawbacks of coaxial line feeding technique, we have used microstrip line feed for designing of a microstrip patch antenna array with FR-4 substrate, that consists of two radiating elements or patches connected together by means of corporate feed which makes the design to obtain a simple planar structure(fig.2.). However as the thickness of the dielectric substrate being used, increases, surface waves and spurious feed radiation also increases, which hampers the bandwidth of the antenna. This method helps in improving the gain and directivity of the antenna which could be obtained in a compact structure. Corporate feed includes the use of quarter-wave transformers in the design process. Quarter-wave transformers aid in providing proper impedance matching between the two patches by using T-junction configurations in the design.
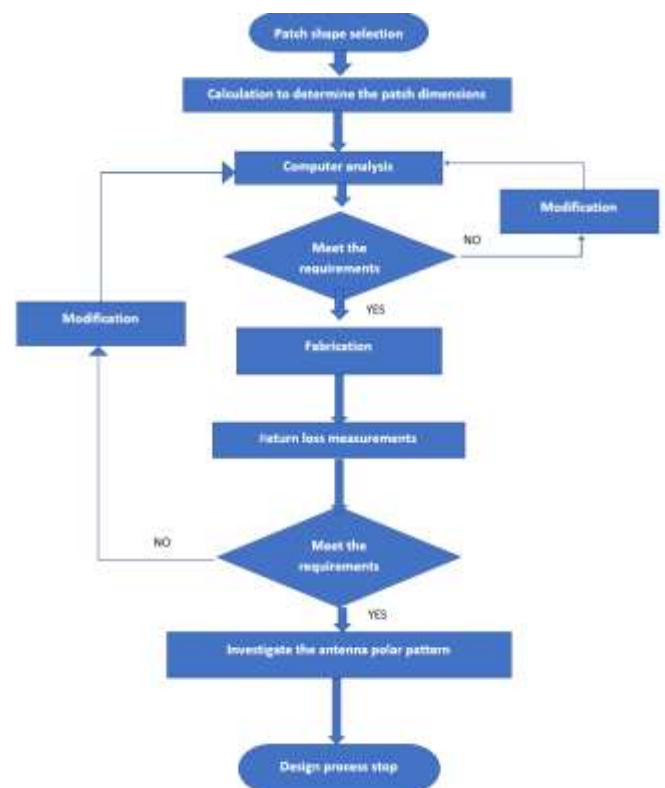
4. FLOW

Figure 3. Flow of design process

5. ANTENNA DESIGN

5.1 SINGLE PATCH

In this section dimensions of a rectangular patch antenna fed by microstrip line will be derived using equations(1)-(6).We used FR-4 (flame resistant) lossy material as the substrate with a dielectric constant of 4.4 and a loss tangent ranging from 0.017 to 0.025.This substrate is generally preferred for better radiation and antenna gain at low cost.

TABLE I. RECTANGULAR PATCH ANTENNA THEORTICAL DIMENSIONS

Table 1. Dimensions of a single patch antenna

h (mm)	1.6
W (mm)	12.95
ε_{eff}	3.87
ΔL (mm)	0.726
L (mm)	25.02
$Lsub$ (mm)	27.14
$Wsub$ (mm)	22.79
t(mm)	1.6

We will be designing the patch antenna array using the CST Microwave Studio Suite (Computer Simulation Technology). Gain of single patch is obtained as 2.8dBi.

5.2 PATCH ANTENNA ARRAY

The gain of a single patch does not exceed 7 dBi.
For the systems of the 5G, 7 dBi is very little value; it should be improved by the use of an antenna array which gives a high value of gain compared to a single patch [12]. Also the fractional bandwidth will be improved compared to a single patch which is of 3%. The adaptation to 50 ohms is necessary to ensure good operation of the antenna. In order to power a two-element antenna array, a T-junction is used. There are several T-junction configurations with different calculation methods. This technique allows having a good impedance matching over a wide frequency band.
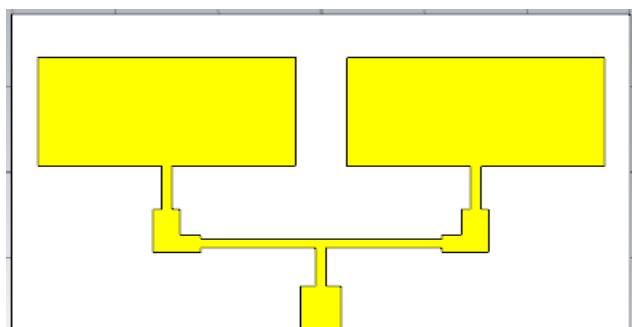

Figure 4. Designed Patch Array Antenna

Fig.4 shows the proposed design of 2*1 microstrip patch antenna array, with each patch designed using the dimensions given in table 1. The quarter-wave impedance transformer is a transmission line or waveguide used in electrical engineering of length one-quarter wavelength terminated with some unknown impedance(ZL) .It presents at its input(ZIN) the dual of the impedance with which it is terminated which is given by equation(7)

$$\frac{Z_{in}}{Z_0} = \frac{Z_0}{Z_L} \qquad (7)$$

Generally the quarter-wave transformer is used for matching the impedance at the input with the impedance at the output by varying it's impedance with respect to the characteristic impedance of the circuit(ZO).Thus we have used quarter-wave transformer for matching the impedance of the patch with the impedance of the feed line. Table 2 shows the dimensions of 2*1 patch array antenna.

Table 2. Dimensions of 2*1 patch array antenna

h(mm)	1.6
W(mm)	12.95
L (mm)	25.02
$Lsub$ (mm)	60
$Wsub$ (mm)	36.79
d (mm)	5

## 6. SIMULATION RESULTS

6.1 S-PARAMETER
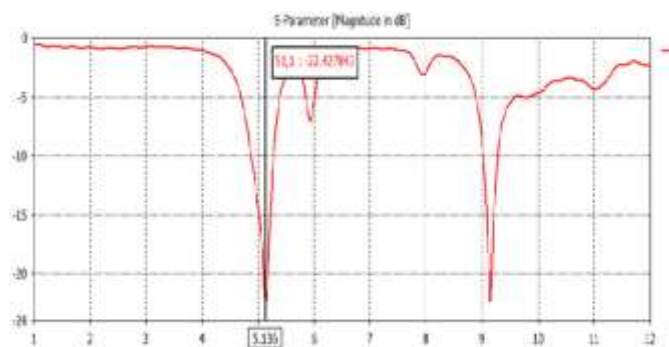
S-parameter refers to Scattering parameter which is represented in matrix form. It describes input-output relation between ports in an electrical system. Many electrical properties of network of components may be expressed using S-parameters, such as gain, return loss, directivity, Voltage Standing Wave Ratio(VSWR) and reflection coefficient. S11 represents how much power is reflected from the antenna and hence it is known as reflection coefficient.
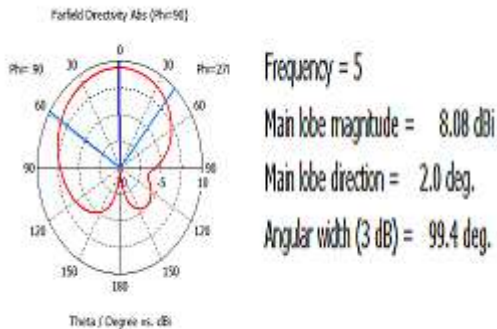
6.2 DIRECTIVITY

Antenna directivity is the ratio of energy transmitted or received by the antenna in a particular

direction to the energy transmitted or received in that direction by an isotropic source.
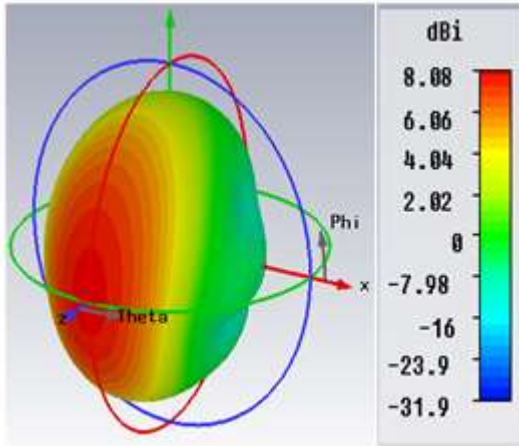
3D plot of directivity

The output for the designed patch array antenna were found and the directivity plot was obtained. The directivity obtained is about 8.08dBi.
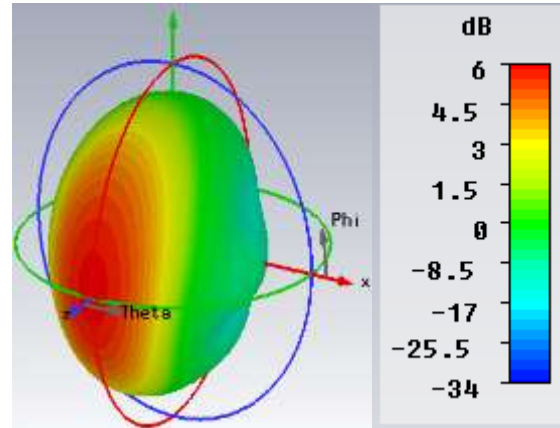

Polar plot for Directivity

6.3 GAIN

Antenna gain in a particular direction is equal to the directivity in that direction multiplied by the antenna efficiency given by equation (8)
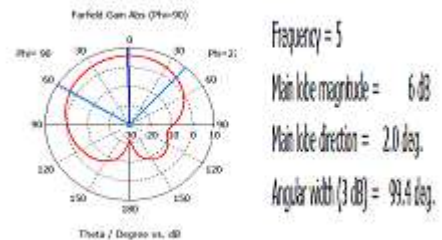
$$G(\theta,\varphi)=E*D(\theta,\varphi) \qquad (8)$$

Gain of the designed patch array antenna is given below.


3D plot of Gain

We have obtained a gain of about 6dB.

Polar plot of gain

6.4 VSWR

The parameter VSWR is a measure that numerically describes how well the antenna is impedance matched to the radio or transmission line it is connected to. VSWR stands for Voltage Standing Wave Ratio which defines how efficiently radio frequency power is transmitted from the power source through a transmission line into the load.
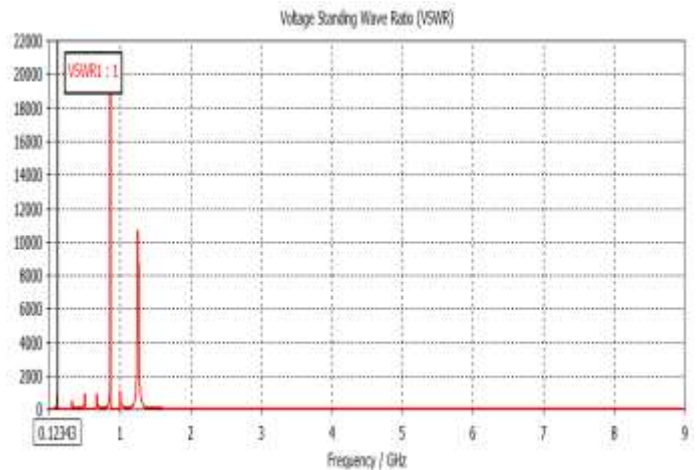
VSWR of patch antenna array

After the design process is completed the patch antenna is fabricated. The fabricated patch array antenna is shown below.
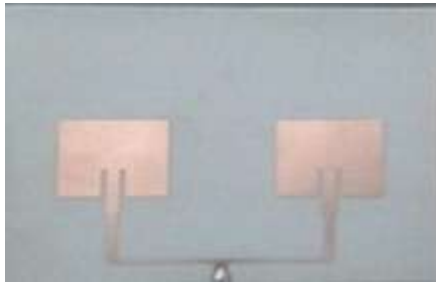
Fabricated design

7. CONCLUSION

The proposed design can be used for different millimeter wave phased array applications and due to the compact size, they could be used in Wi-Fi, Wi-Max and WLAN applications. Due to the extremely high speed of 5G, the proposed design could be used widely in applications requiring high data rates in near future.

8. REFERENCES

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