


# Design and Implementation of Microstrip Patch Antenna Array for “5G” HD Live Video Streaming Applications

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**Abstract**—for 5G applications, a Microstrip Patch Antenna and its array of 1x8 are suggested. The 5G metal conducting Patch is built on a roger RT Duroid 5880 substrate with a standard thickness of 0.7123mm, a dielectric permittivity of 2.2 and loss tangent is 0.0009. The Antenna has a S11 parameter of -22.68dB and a bandwidth of 1.8 GHz. In order to increase the gain and bandwidth of proposed design, taper line feeding is used to create an array of 1x8 elements for the desired antenna. The Antenna array is tuned to the same 30GHz frequency. With the array of antennas, there is a noticeable boost in gain and increase in bandwidth. Because of its small size, for 5G mobile broadcasting, the Microstrip Patch Antenna and its array of 1x8 elements are appropriate.

**Keywords**— Micro strip Patch antenna, Resonance frequency, Feed line, Rogers RT 5880.

## I. INTRODUCTION

There is an urgent requirement of uninterrupted and uninterruptible data rate, specifically progressing countries like Pakistan, Afghanistan and Iran etc. For that purpose, 4G mobile communication is not enough, because of low radiation gain and limited bandwidth (BW). Nowadays, Microstrip Patch Antennas are crucial, and have been employed in the 5G range to attain the required gain and bandwidth. There are several kinds of Microstrip Patch Antennas (MSPAs) [1]. They come in a several sizes and shapes. For instance, rectangular, triangular, square and circular shapes. While the rest of shapes are, trapezoidal, ring and “E” shapes. Among them the most commonly used Antenna is rectangular Microstrip Patch antenna. We are concerned with the rectangular Microstrip Patch antenna. Metallic Microstrip Patch Antenna plays a pivotal role in the area of exchange of information’s or ideas through space in telecommunications sector. It is consisted of a metallic Patch which is connected with a field line. Normally the Patch and field line made up of same metal like gold or copper. Below the Patch we have a substrate, its thickness

greater than Patch. Make sure that the dielectric constant must be in between 1 and 12. Below the substrate we have ground plan whose thickness closely resembles with the thickness of Patch. The material used in ground plane and metallic conducting Patch is similar and is rarely may be different [2]. The advantages are described one by one as; it is small in size, inexpensive, light weighted and easy to fabricate for the manufacturers. Low input power required for it. The disadvantage of the Antenna is expressed as; it has a narrow bandwidth, low efficiency and low gain. The applications of Microstrip Patch Antenna are described as; Due to their affordability, portability, and light weight, an array of antennas is used in cellular phones, radar and sonar systems for the use in military purposes. It is also used in space broadcasting as well as wireless technology specifically in 5G standard [3]. The length of the Patch could be chosen  $0.333\lambda < L < 0.5\lambda$  where  $\lambda$  is free space wavelength and  $t \ll \lambda$ . It is quite simple and easy to construct and fabricate. It has a rectangular shape ground, and upon which a substrate is built [4]. Substrate may be any material like Rogers RT 5880, Rogers RT 3003 or another material, but make sure that the dielectric constant of the material “ $\epsilon$ ” must ranges from 1 to 12, and in the proposed work we used Rogers RT Duroid 5880. The metallic conducting Patch is mounted on the top of the substrate having height “ $h$ ”, and it may be any kind of metal, like gold, copper etc. The metallic Patch is responsible to radiate energy along its width-wise [5]. Feed line is connected with the conducting Patch, the thickness of feed line and metallic Patch is same. The thickness of ground plane and Patch often same but in rare cases might be little bit different [6]. If the transmitter and receiver don’t communicate via line of sight, the signal can easily penetrate the walls at lower frequencies and higher wavelength, resulting in some attenuation. Another issue is that fabrication gets more complex at higher frequencies and shorter wavelength [7]. For the increasing demand of data rate in the telecommunications sector, improvements in mobile technology have benefited mobile services to the extent, that there is now a lot of congestion in the frequency bands happened. As it is expected to be the

most powerful and advanced wireless technology in the coming years, 5G is currently a very interesting subject in the global telecommunication business [8]. Creating slots at the centre of metallic conducting Patch, there is a reasonable improvement in gain as well as bandwidth occurs. Because of creation of slots, there are a reduction in Patch size happened, and also the direction of current has been changed [9]. Increasing demand of data, single Patch Antenna is not enough; in order to cope up the situation we design an array of 1\*8 element antenna, with improved gain, bandwidth and  $S_{11}$  parameter [10]. On the Roger RT Duriod 5880, a micro-strip Patch Antenna is constructed that resonates at 30GHz. This paper is arranged in such way that, Section II represents design zone Section III denoted results and discussion. Decisively conclusion provided at section IV and then references.

## II. CONSTRUCTION OF PATCH ANTENNA

### A. 5G Antenna Construction

A metallic single Patch Antenna with dimensions of  $4 \times 4.03 \times 0.7123$ mm is constructed using a substrate Rogers RT 5880 with a dielectric permittivity of 2.2 and a ground plane with a value 0.000875 is presented in the following Figure 1. The Antenna resonates at 30GHz, giving a return loss of -22.68dB and bandwidth of 1.8GHz. Where “W” and “l” are the width and length of substrate respectively, whereas “ $W_p$ ” and “ $l_p$ ” are width and length of Patch and “ $l_f$ ” and “ $w_f$ ” are the length and width of feed-line respectively.

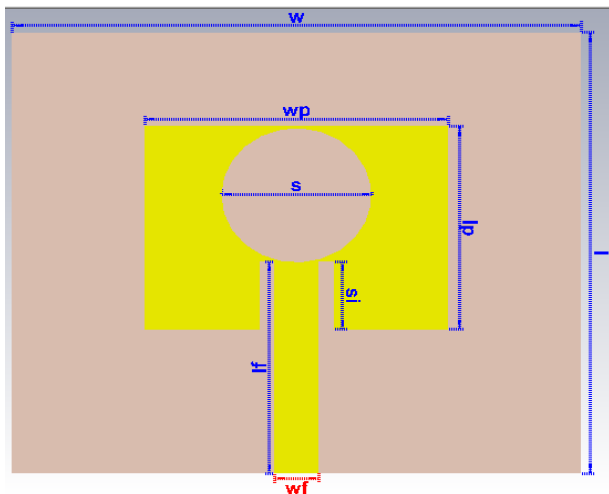


Figure 1: Single Patch Antenna Design

A slot “s” has been created at the center of metallic Patch with a diameter “ $d_i$ ” is 1.98mm, while thickness equal to the ground plane and a slit “ $s_i$ ” is created between feed line and metallic Patch on both sides, having length “ $l_i$ ” is 1mm and width “ $w_i$ ” is 0.2mm respectively. The variables used to construct micro-strip Patch Antenna in software CST studio 2019 are given in the following table

TABLE 1

### PATCH ANTENNA SIMULATION PARAMETERS

Parameter	Symbol	Value
Permittivity	$\epsilon_r$	2.2

Resonance frequency	$f_r$	30GHz
Patch width	$W_p$	4mm
Patch length	$l_p$	3mm
Substrate width	w	4mm
Substrate length	l	4.03mm
Feed-line length	$l_f$	2.12mm
Feed-line width	$W_f$	0.579mm

The design parameters are listed in the above table1. As discussed in previous section that the single Patch Antenna gain, bandwidth, VSWR, directivity,  $S_{11}$  parameter are quite small, in order to operate according to the modern 5G data requirement. So, we are going to construct an array of 1x8 antennas, which will give us better results than the single Patch antenna, which is discussed in the next section briefly.

### B. 5G Antenna array

We designed micro-strip Patch Antenna in the previous section and has been observed results, after observation of results we came to a point that single element of Patch Antenna has very low gain, narrow bandwidth and bad return loss. The general formula for constructing nth array Antenna is 1xn. Patch Antenna is single when n=1, 1x2 when n=2, 1x3 when n=3, and so forth. In the 1x8, n=8 design, proposed. In order to improve these results, we are going to design a metal conducting micro-strip Patch Antenna array of 1x8 elements. Table 3 is the details of parameters of 1x8 Patch Antenna array.

TABLE 2

### Micro-strip Patch Antenna array design parameters

Description	Symbol	Values in (“mm”)
Substrate’s length	L	16.5
Substrate’s width	W	62
Substrate’s breadth	h	0.7123
Ground depth	g	0.000875
Tapper line width	$W_1$	2.295
Tapper line length	$h_1$	1.601
Distance b/w two Patch es	d	2.97
Width above the h1	$W_2$	28.66
Width represented in fig;	$W_3$	14.734
Width represented in fig;	$W_4$	7.36
Slot diameter	$d_i$	1.98
Slot depth	$s_d$	0.000875
Slit length	$l_i$	1
Slit width	$w_i$	0.2

With the advancement in telecommunication and the increasing usage of internet in the world we require an uninterrupted data rate within the various institutions and offices across the world specifically in the developing countries like Pakistan, India etc. In order to overcome this situation, we design an array of 1\*8 micro-strip Patch Antenna which is shown in diagram below. The Antenna array is constructed using a taper line, and the distance between two consecutive metallic Patches is denoted by “d” and its value is  $d= 2.97\text{mm}$ .

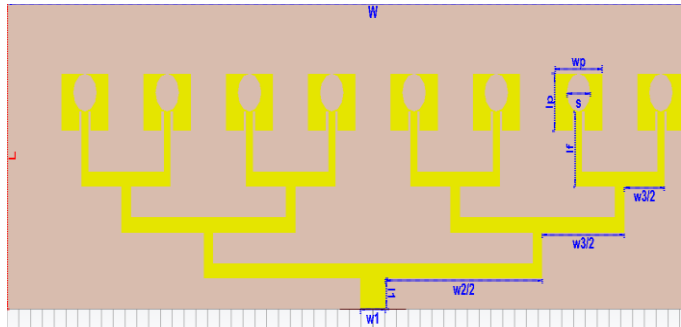


Figure 2: Patch Antenna array of 1x8

Array of Antenna is an arrangement of metallic Patches placed adjacent to one another. These Patches are mounted on a Rogers RT Duroid 5880 substrate. By constructing properly constructive and destructive interference takes place. During constructive interference addition of positive sides of waveform occurs while during destructive interference cancellation of negative sides of waveform takes place. Arrays of antennas were first employed in radar and sonar systems. They are now widely used in satellite and mobile communications. A 1x8 array is proposed in this paper. Taper line feeding is used to design the array. 2.97mm is the distance between two successive Patches, which is shown in the Figure 2. A comparison of the characteristics of a single Patch Antenna and its array has been taken.

### III. RESULTS AND DISCUSSION

#### A. Return Loss

While designing Microstrip Patch Antenna a response has been taken between magnitude of  $S_{11}$  and frequency, which is called return loss. It is actually the power reflected back and loss, so the power which is return and then loss is known as return loss. It is the excellent way to find out the signal source input and output. Return loss or  $S_{11}$  parameter can be calculated in terms of dB. For a complete matching between Antenna and transmitter or receiver,  $T=0$  and  $S_{11}$  parameter  $=\infty$ , which indicates that there is no power reflected back. But when the  $T=1$  and  $S_{11}$  parameter  $=0\text{dB}$ , all the power reflected back and loss. In the proposed metallic conducting Microstrip Patch Antenna the  $S_{11}$  parameter is  $-14.02\text{dB}$ , which is shown in Figure 3. Return loss below than  $-10\text{dB}$  is acceptable and bandwidth can be determined with the help of return loss graph, as the difference between lower frequency and higher frequency at  $-10\text{ dB}$  return loss. Return loss or  $S_{11}$  parameter of 1\*8 Antenna array is very good which  $-46.7\text{dB}$  approximately, and bandwidth is approximately 2GHz, figuratively described in Figure 4. If we compare both the graphs, return

loss of Antenna array has been found very efficient than the single Patch Antenna approximately.

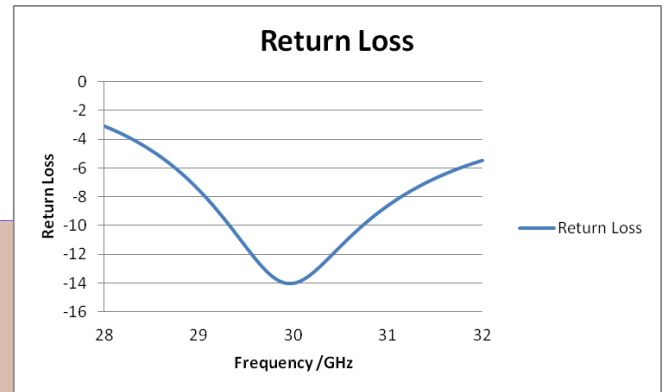


Figure 3:  $S_{11}$  parameter of single Patch antenna

The comparison of bandwidth between the Figure 3 and Figure 4 is  $(2.1\text{GHz}-1.4\text{GHz}) = 0.7\text{ GHz}$  increased, it means that a considerable amount of bandwidth enhanced.

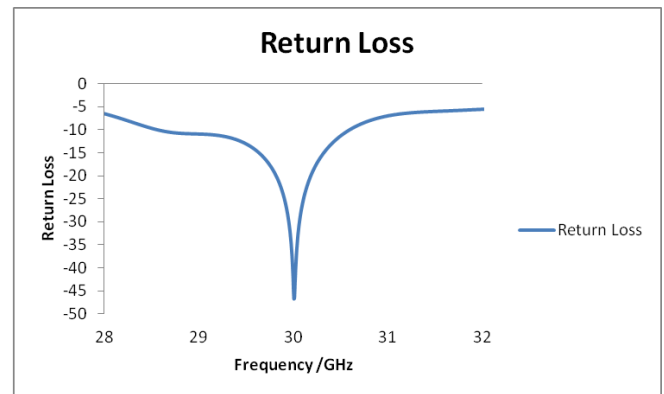


Figure 4:  $S_{11}$  parameter of 1x8 Element Array

#### B. Voltage Standing Wave Ratio (VSWR)

Relationship between voltage and standing wave ratio is starts from 1 and goes up to  $\infty$ . So the best impedance matching lies in the range of  $2 < \text{VSWR} > 1$ . The comparison has been carried out between voltage standing wave ratio (“VSWR”) Figure 5 and Figure 6 is 1.15 and 1.02 respectively. The “VSWR” closer to 1 is better than greater than one. So, 1.02 is better than 1.15. So, the voltage standing wave ratio (“VSWR”) closer to one is best, we can say the microwave lines matched more closely with the load in the later one as compared to first one.

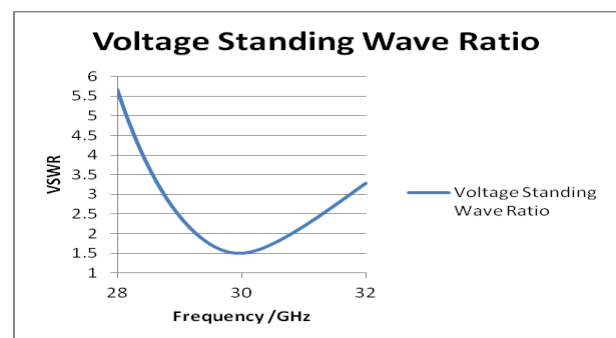


Figure 5: VSWR of Patch Antenna

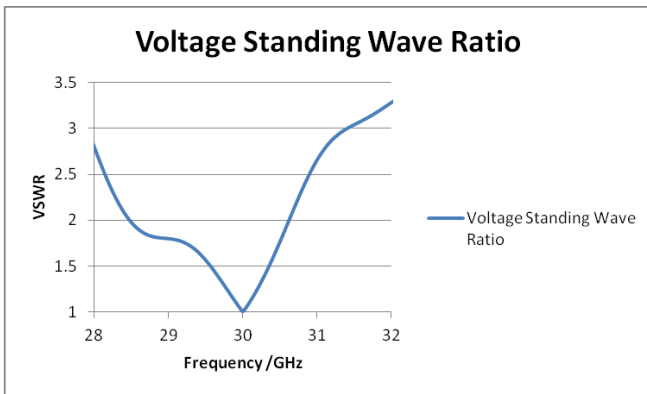


Figure 6: VSWR of Patch Antenna Array

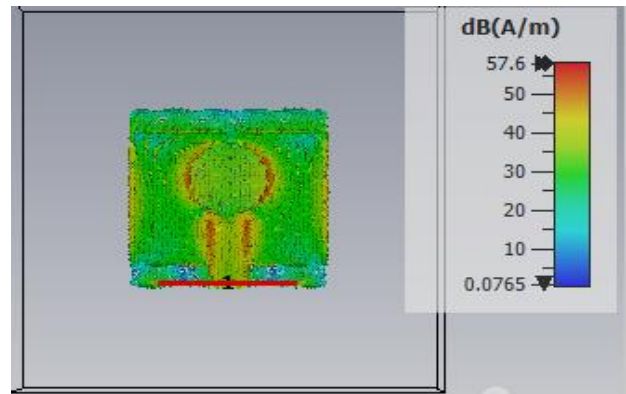


Figure 7: Current Distribution in Patch Antenna

### C. Gain and Frequency

Antenna gain is actually a quantity which gives a better performance to the radiation of Antenna in a particular direction. For the 5G single Patch Antenna and its array, gain and frequency plots, as well as 3D gain charts, are displayed in Figure 11 and Figure 12 respectively. At the same frequency range, evidently the Antenna array's gain is higher than the metallic single Patch antenna. The gain of a single Patch 5G Antenna at 30GHz is 3.26dB. The 1\*8 Antenna Array has a gain of 13.6dB at the same frequency. This is approximately 5 times has been increased as compared with the single Patch Antenna, which is shown in Figure 11 and Figure 12 respectively. While the bandwidth of Single Patch Antenna has been noticed 1.4GHz and 2.1GHz has been noted in case of Microstrip Patch Antenna Array.

TABLE III

THE SUGGESTED PATCH ANTENNA AND ITS ARRAY'S GAIN

Name	Single Patch	1x8 Patches
Resonance frequency	30GHz	30GHz
Gain	3.26dBi	13.6dBi

### D. Current Distribution

Figure 7 and Figure 8 depicts the surface current distribution for a single Patch Antenna and its array. The metallic Patch Antenna has the majority of the radiation appears from the Patch at the resonate frequency, and the same thing happened with the array. In comparison to a single micro-strip Patch antenna, the current is greater at its array Patches. Which confirmed the more impedance matching at array antenna. When the signal moves through the feed line, it gets attenuated as the greenish color represents the attenuation. While the red color represents the minimum surface current distribution as in Figure 7 across the corners of the Patch appears. In Figure 8 the distribution of surface current in terms of dB..

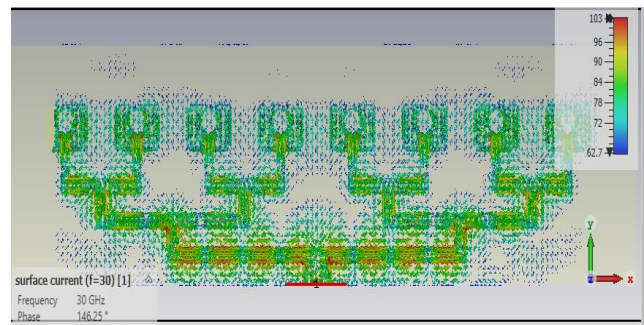


Figure 8: Current Distribution in Patch Antenna Array

### E. 2D and 3D Plots

Figure 9 and 10 has been described the 2D Farfield Gains of Microstrip Patch Antenna and its Array. In comparison to Antenna Array, the 5G Patch Antenna's far field polar plot has been shown bad performance. The major lobe magnitude of 7.65dB with a direction of 9 degree. The side lobe level is noted -10.0dB with angular width 65.6 degrees. While in case of array, main lobe magnitude 13.6 dB and its direction is 34 degrees. The side lobe is -4.1dB noted and its angular width 50.2 degrees. Both are shown in the Figure 9 and 10 respectively.

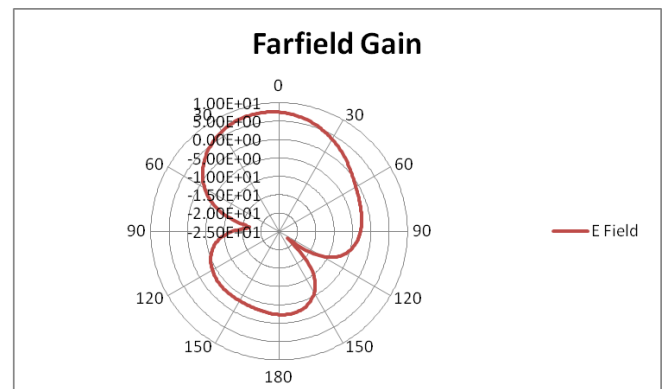


Figure 9: 2D Plot of Patch Antenna

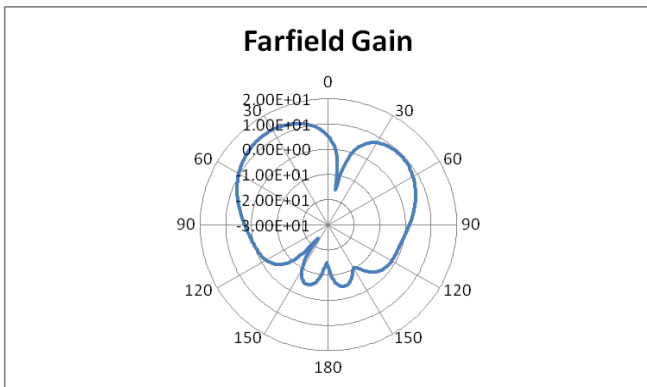


Figure 10: 3D plots of Patch Antenna Array

It has been compared the 3D plot of single Patch Antenna with the 3D plot of Antenna array, it can be observed clearly that the 3D radiation pattern of Antenna array is more directed along the theta direction as compared with the single Patch antenna. Radiation pattern in Figure 11 and 12 are shown below respectively, the maximum gain represented by the red color and its highest value in case of Patch Antenna is 3.26dBi, while minimum is -36.7dB. In case of Antenna array described in Figure 12 the maximum radiation gain is 13.6dB and minimum -26.4dB. It has been revealed from both Patch Antenna Array 5times greater than Patch Antenna

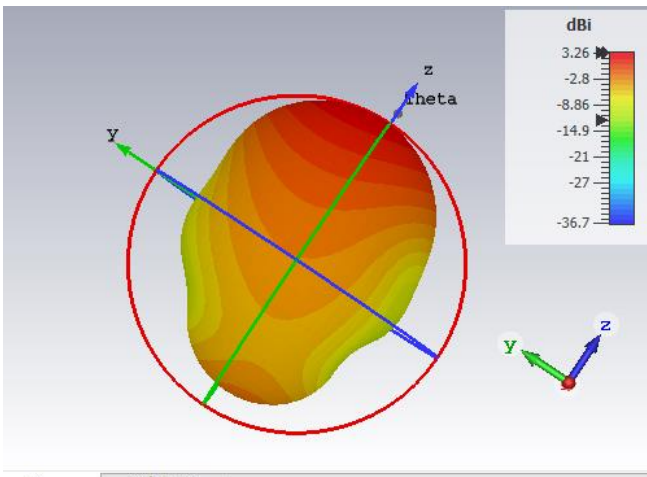


Figure 11: 3D Plot of Patch Antenna

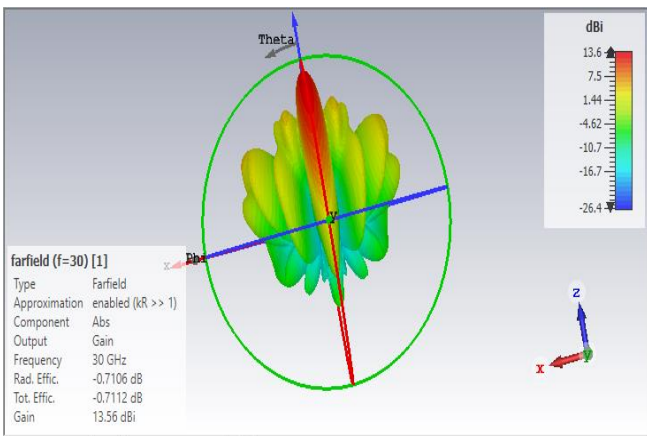


Figure 12: 3D Plot of Patch Antenna Array

#### F. Efficiency

Figure 13 and 14 has been described radiation efficiency and total efficiency of Microstrip Patch Antenna Array. In

Figure 13 as the radiation efficiency throughout the bandwidth has been noticed 0.855 in decimal system, by conversion into percentage it is noted about 85.5% approximately. Correspondingly, in case of Figure 14 the total efficiency over the bandwidth has been noticed 0.84, which in terms of percentage 84 approximately. The total efficiency lower than the radiation efficiency, because of some extra losses has been occurred in case of total efficiency.

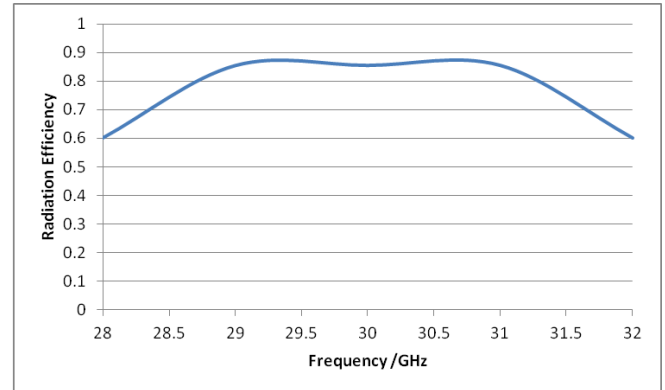


Figure 13: Radiation efficiency of Patch Antenna Array

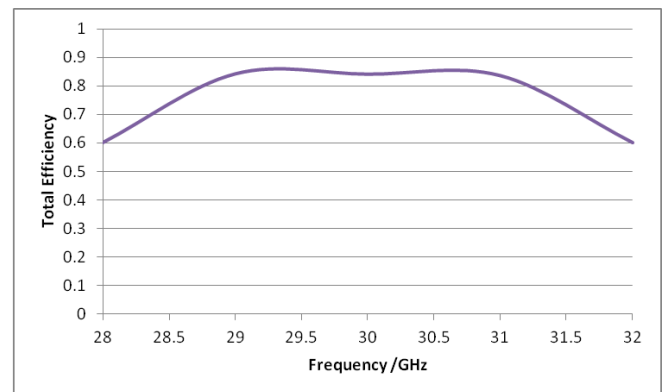


Figure 14 :Total Efficiency of Patch Antenna Array

#### CONCLUSION

In the upcoming applications, a light weighted and low-profile micro-strip Patch Antenna is suggested. The Antenna resonates at a resonance frequency of “30 GHz”; and its array has the same resonance frequency as well, which is in the “5G” wireless standard range. The “5G” Antenna array shows a significant increase in gain, as well as a slight increase in bandwidth. Proposed design has been finished and effectively implemented; it may be used for high degree of excellence online learning or educating students, as well as for downloading and uploading any “HD” videos and other “5G” applications. The total radiation efficiency is approximately 85%, which is good and well and return loss of -46.7dB. Because of its compactness and small size, the metal conducting Patch Antenna and its array can be employed in the upcoming wireless broadcasting. In the upcoming days, one can improve its bandwidth as well as gain, by creating slots at particular positions. There would be chance of increasing its Patches, keep in mind that cost as well.

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