

# MIMO Patch Antenna for Cellular Communication

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## Abstract

MIMO antenna is the key requirement to implement 5G Technology. In order to achieve desired radiation pattern, antennas in MIMO technology are fed with signals which are different in amplitude as well as different in phase. In this research a 16 element MIMO antenna is designed and analyzed in order to achieve isotropic radiation pattern. The designed antenna is suitable for use in cellular communication. The achieved radiation pattern of designed antenna consists of four major beams, each having gain of 12.22 dB and located at 90° apart in space. The designed structure is simulated and analyzed using High Frequency Structure Simulator (HFSS). Designed structure of MIMO antenna is fabricated and results are verified by using Vector Network Analyzer.

Index Terms— Multiple Input and Multiple Output Antenna (MIMO), Patch antenna, Radiation pattern.

## 1. Introduction

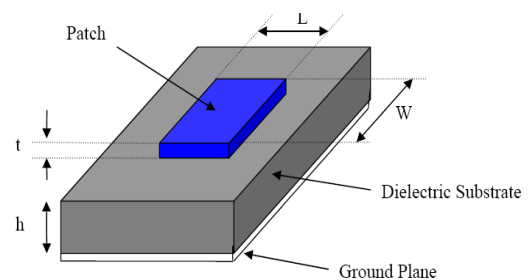
These days wireless technology is evolving at a very fast rate and it is this technology which is responsible for connecting various devices through Internet of things. In order to achieve reliable communication between various devices a high data rate and high channel capacity is required. A high data rate and high channel capacity is achievable due to implementation of 5G Technology [1-5]. Using 5G technology enables communication of several real time devices. [6-9]. Antenna plays an important role in deploying 5G technology. The requirement of high gain, high bandwidth from antenna system can be met up to a great extent by using multiple input and multiple output (MIMO) technology. In MIMO system multiple antennas are fed with input signals which are different in phase and amplitude. Difference in phase and difference in amplitude is in line with antenna array theory for the desired radiation pattern.

This research presents a 16 element MIMO antenna in order to achieve high gain and isotropic radiation pattern. The phase between array elements is kept at 90° so as to produce four main beams which are separated by 90° in space. The designed antenna structure is simulated by using High Frequency Structure Simulator. Designed structure is fabricated by using phase shifters. Fabricated antenna structure is analyzed by using vector network analyzer. The proposed MIMO antenna can be potentially used in 5G base stations.

## 2. Design of Radiating Element

In this research we are using patch antenna as the basic building block of MIMO antenna. The structure of patch antenna includes a radiating patch on one side of substrate and ground on other side of patch as

shown in Fig (1). Signal to be radiated is applied between patch and ground. The frequency and efficiency of radiation for Patch antenna depends on the dimensions, structure, and material of both patch and substrate. Radiation frequency and efficiency of a patch antenna is dependent on the length of patch antenna and width of patch antenna respectively. The optimized expressions proposed for design of patch antenna are [10-13].



**Figure 1. Patch Antenna**

For radiating a signal of frequency ( $f$ ), required patch antenna width ( $w$ ) is

$$w = \frac{c_0}{2f\sqrt{\frac{\epsilon+1}{2}}} \text{-----(1)}$$

Here  $\epsilon$  is the permittivity of the substrate.

Here  $c_0 = 10^8 \text{m/s}$  is velocity of light.

The effective optimized permittivity of medium is

$$\epsilon(\text{eff}) = \frac{\epsilon+1}{2} + \frac{\epsilon-1}{2} \sqrt{1 + 12 \frac{h}{w}} \text{-----(2)}$$

$h$  is substrate height.

Optimized required Patch antenna length ( $L$ ) is

$$L = \frac{c}{2f\sqrt{\epsilon}} - 2\Delta l \text{-----(3)}$$

Here  $\Delta l$  is extension in length of patch due to available fields.

$$\frac{\Delta l}{h} = .412 \frac{[\epsilon(\text{eff})+.3] \left[ \frac{w}{h}+.264 \right]}{[\epsilon(\text{eff})-.258] \left[ \frac{w}{h}+.8 \right]} \text{-----(4)}$$

Based on above mentioned equations dimensions of substrate and Patch antenna are mentioned below.

**Table 1:** Patch antenna parameters

Patch Material	Perfect Electric Conductor
Patch Length	13.14 mm
Patch Width	15.70 mm
Material of Substrate	Rogers RT
Dielectric constant of Substrate	2.2
Substrate height	508 mm
Operative frequency	7.55 GHz

Array of Patch elements are used to achieve high gain and isotropic radiation pattern. The radiation pattern of antenna array can be calculated by multiplying the radiation pattern of single element and antenna array factor.

For N element antenna array in one dimension array factor is given by

$$AF(\theta) = \sum_{n=1}^N I_N e^{i\alpha} e^{(ikd \cos \theta)} \text{----- (5)}$$

Here antenna elements are separated by distance d.  $I_N$  is the magnitude of feeding current to various elements.  $\alpha$  Is the progressive phase shift between antenna elements. The point of observation makes angle  $\theta$  with array axis and  $k$  is phase shift constant.

Enhanced beam steering and side lobe reduction can be achieved by arranging antenna elements in two dimensional arrays. When antenna elements are arranged in two-dimensional structure then array factor is given by

$$AF(\theta, \varphi) = \sum_{m=0}^{M-1} \sum_{n=0}^{N-1} I_{mn} e^{i\alpha_{mn}} e^{(ik \hat{r} \cdot \vec{r}_{mn})} \text{----- (6)}$$

$I_{mn}$  is the magnitude of feeding current of  $mn^{th}$  element.

$\vec{r}_{mn}$  Is the location of  $mn^{th}$  element.

$$\vec{r}_{mn} = x_{mn}\hat{x} + y_{mn}\hat{y} + z_{mn}\hat{z}$$

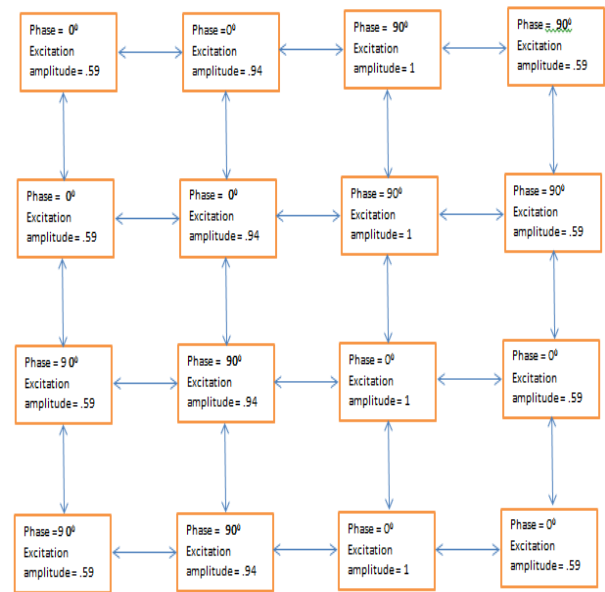
And

$\hat{r}$  is the location of observation point

$$\hat{r} = \sin \theta \cos \phi \hat{x} + \sin \theta \sin \phi \hat{y} + \cos \theta \hat{z}$$

$\alpha_{mn}$  is the excitation phase difference between elements.

Based on above theory proposed design of Patch antenna array along with their feeding phase is given in Fig (2).

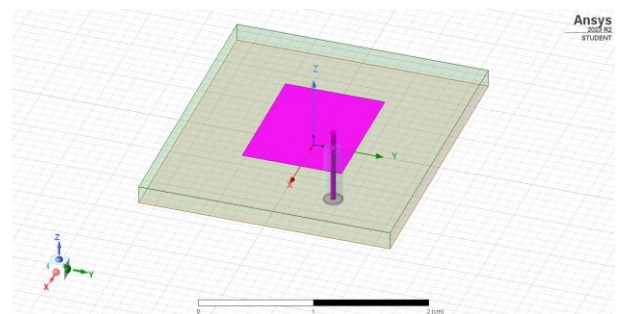


**Figure 2.** Proposed antenna array

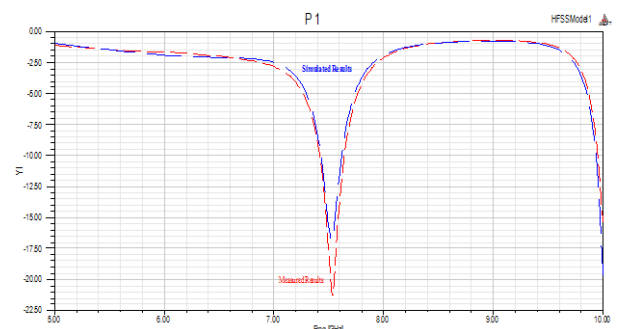
The structure of Proposed antenna array is designed and analyzed using High Frequency Structure Simulator and finally designed structure is analyzed by using vector network analyzer.

**3. Results and Discussion**

Several prototypes of MIMO antenna are designed and analyzed using HFSS. The designed patch antenna with dimensions as mentioned in Table 1 is designed and fabricated. The designed coaxial fed patch antenna is shown in Fig (3). Designed patch antenna resonates at 7.5 GHz. The simulated and measured return loss  $S_{11}$  of designed antenna are plotted in Fig (4). Simulated and fabricated results indicate a return loss of be -16 dB and -21 dB respectively at 7.5 GHz.



**Figure 3.** Patch antenna designed in HFSS



**Figure 4** Return loss of Patch antenna

The maximum obtained directive gain of patch antenna is 7.15 dB in boresight direction as shown in Fig (5) and Fig (6).

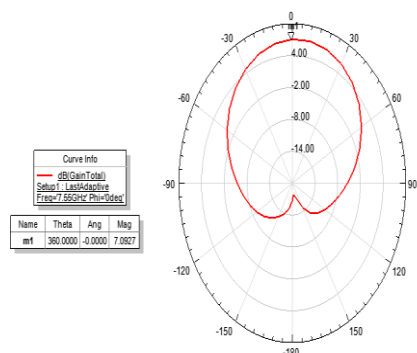


Figure 5 Directive Gain of Patch antenna

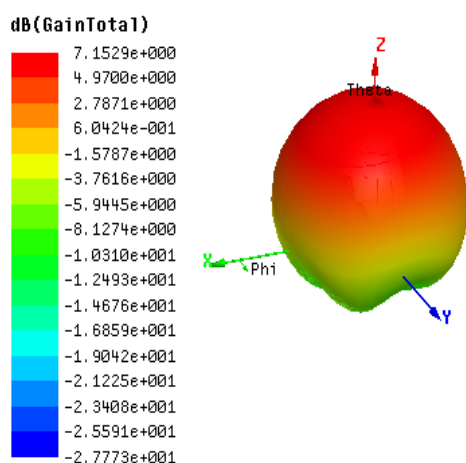


Figure 6 Directive Gain of Patch antenna

Designed MIMO antenna of 16 elements is as shown in Fig (7).

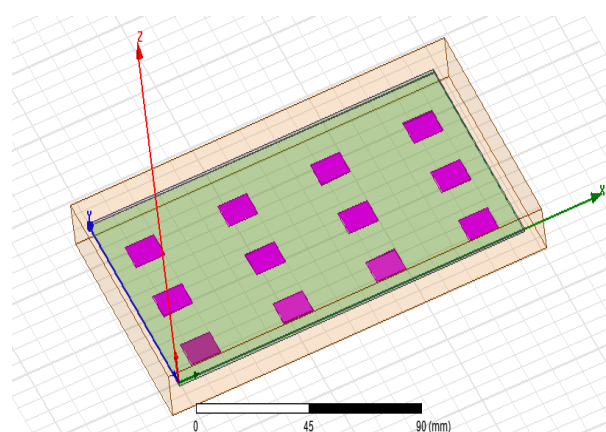


Figure 7. MIMO Antenna designed in HFSS

Fabricated prototypes of MIMO along with VNA is as shown in Fig (8). Fabricated MIMO antenna is analyzed using VNA. MIMO antenna is fed as per fig (2).



Figure 8 Fabricated MIMO antenna along with VNA

The radiation pattern of designed MIMO antenna is as shown in Fig (9). Four major lobes having gain of 12.22 dB and located at 90° apart are achieved. The gain of fabricated structure is also measured using VNA and Horn antenna. The achieved gain of major lobe for fabricated structure is 11.8 db.

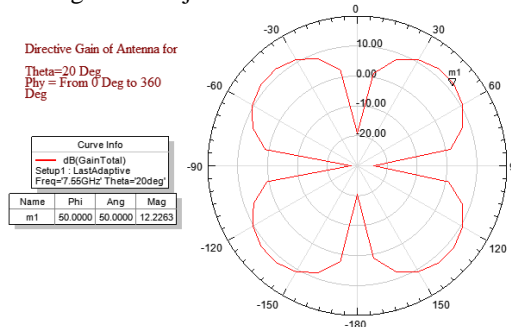


Figure 9 Radiation Pattern of MIMO antenna

**Conclusion:**

A 16 element MIMO antenna having isotropic radiation pattern is designed and fabricated. This MIMO system can be potentially used in base station of cellular system.

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