Antenna Design for 4x4 MIMO 5G Communication

Kalpita B Velip[1], Sangam Borkar[2]

[1]*Student, Dept. of Electronics and Telecommunication Engineering, Goa Engineering college, Goa, India.*
[2]*Assistant Professor, Dept. of Electronics and Telecommunication Engineering, Goa Engineering college, Goa, India.*

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Abstract - *The design presented in the paper for the 5G application (5G NR N78 Band) at the operating frequency 3.5GHz of a patch antenna with U shaped slot was investigated to realise a structured 4x4 MIMO antenna. To widen the bandwidth U-shaped slot was cut out on the microstrip patch antenna that was coaxially fed. FR4 material was used as the dielectric substrate in designing with relative permittivity 4.4 with a height of 1.6mm and loss tangent 0.02. The antenna model was designed and analyzed using HFSS software to obtain a bandwidth of 250 MHz with good performance parameters like VSWR, Gain, Reflection coefficient and Impedance. The parameters and analysis have been added in this paper.*

***Key Words*: Microstrip, 5G NR N78 Band, U-Slot, MIMO, HFSS.**

1. INTRODUCTION

The technology of MIMO (Multiple-input multiple-output), one of the key components playing substantial role in the 5G system of communication can greatly boost spectral efficiency without using additional power. 3GPP (3rd Generation Partnership Project) recognized many licensed and also unlicensed bands which form a wide bandwidth from 3.3GHz to 5GHz as the combination of 5G NR bands N77 (3.3–4.2 GHz), N78 (3.3–3.8 GHz) and N79 (4.4–5 GHz) [2]. The 5G sub-6 GHz spectrum has NR bands N77/N78/N79 its key constituents. The main method for improving all facets of wireless communications is MIMO. It has a significant impact on 5G technology and is changing how everyday people engage with these technologies. By implementing 5G New Radio (NR), data can reach more users and be accessed by more people at the same frequency and time rates. A light-weight and smaller sized antenna is probably recommended to enable the high mobility required for a wireless equipment to communicate. Microstrip antennas that compact enough are among the best tools for this job. Due to their low cost and planar form, microstrip antennas have been extensively well used in modern systems. Cutting a U-shaped slot in the patch of the rectangular patch antenna that is coaxially fed is one way to increase the bandwidth. The finite ground plane and U-shaped slot are employed to produce excellent impedance matching and expand the bandwidth [4]. Due of its benefits, our design takes into account a U-shaped slot on the patch antenna's rectangular shape. For our design, we took into account the coaxial probe feed approach because it is simple and adaptable because it may be positioned wherever is necessary to meet impedance. In this paper a single basic structure of Microstrip patch antenna was considered for designing. The design of a 2x2 and finally 4x4 antenna system with multiple single element antennas were placed compactly in a MIMO configuration.

2. DESIGN OF THE ANTENNA

In-depth study has recently been conducted to improve bandwidth, gain, and offer size utilizing a variety of strategies. These methods include the use of substrates with reduced dielectric permittivity, air-filled dielectric media, thicker substrates, and slot antenna architecture.

Gain can be gained by loading a certain slot on the patch element of the antenna that conducts, which results in a smaller antenna and increased bandwidth. When slots are introduced onto a conducting patch element, the excited patch surface current channels might meander, which lowers the resonant frequency and results in a smaller antenna than a traditional microstrip patch antenna at the intended frequency.

Antenna impedance, bandwidth, gain, and size properties are improved by loading slots on the conducting patch element with a thick air dielectric material and igniting it with a single coax feed setup.

In the given frequency range, the coaxial feeding technique has advantages over the microstrip line feeding technique for antenna characteristics. Overall, coaxial feeding produces superior outcomes. compared to micro strip line feeding, ignoring gain, for all antenna parameters.

In Fig. 1, Fig. 2 and Fig.3 the rectangular U-slot patch antenna's geometry which is proposed above is shown.

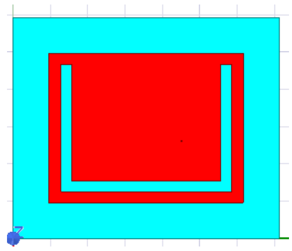

Fig -1: HFSS model of a U-slot Rectangular Patch Antenna

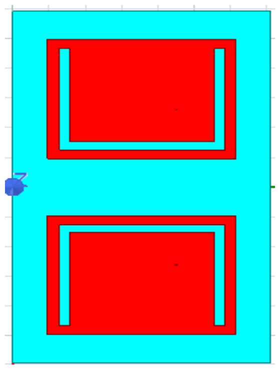

Fig -2: HFSS model of a 2X2 MIM0 U-slot Rectangular Patch Antenna

The two single U slot antenna which are coaxially fed are placed opposite to each other in a symmetrical manner and the results are obtained.

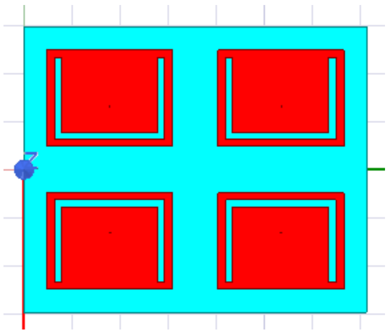

Fig -3: HFSS model of a 4x4 MIM0 U-slot Rectangular Patch Antenna

Finally, the 4x4 MIMO antenna configuration is achieved after placing multiple antennas compactly in the total area and achieving the feed location after iterating for the best impedance match.

Fig.4. shows the detailed dimensions of the single patch antenna where Lg is the ground plane length and Wg as the width and the patch length and width are L and W respectively. The patch consists of a U-slot with the following dimensions: D for the slot width, C for the slot height, H for the slot height from the patch base, and E and F for the slot width between the upper and lower layers of the U-slot.

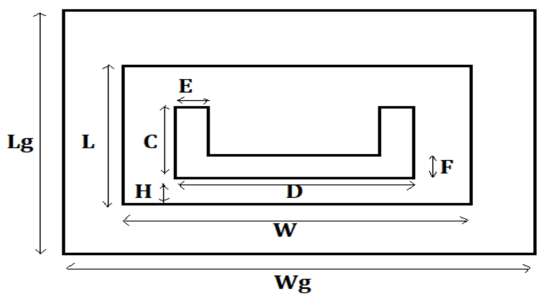

Fig -4: U-slot microstrip Patch Antenna's dimensions

3. DESIGN CONSIDERATIONS

The center frequency (fo) is taken as 3.5 GHz with lower bound frequency (flow) as 3.3 GHz and upper bound frequency (fhigh) as 3.8 GHz. The antenna was designed for the application of 5G for the 5G NR N78 band. Dielectric material FR4 with dielectric constant 4.4 and loss tangent 0.02 was used. Substrate height was taken as 1.6 mm.

DESIGN EQUATIONS

Patch Dimensions:

1) Width

$W = c0\ 2f0 \sqrt{2/(1+\varepsilon r)}$

2) Effective dielectric constant

$\varepsilon reff = \varepsilon r + 1\ 2 + \varepsilon r - 1\ 2 \sqrt{[1 + 12\ h\ /\ w]}$

Length extension

$\Delta L = 0.412h\ (\varepsilon reff + 0.3)\ (W/h + 0.2)/\ ((\varepsilon reff - 0.258)\ (W/h + 0.8))$

3) Length

$Leff = (C0/2f0\sqrt{\varepsilon reff}) - 2\ \Delta L$

Ground dimensions:

1) Width of the ground

$Wg = W + 6h$

2) Length of the ground

$Lg = L + 6h$

The most popular method of feeding Microstrip patch antennas is employed i.e. coaxial-probe feeding. This type of feeding technique has the key benefit that the feed can be placed anywhere it is needed inside the patch to match the input impedance [8]. After several iterations, its position on the patch determined the impedance match that were estimated to meet a 50ohm impedance.

The various design parameters that were calculated for the single element of the MIMO antenna configuration are provided below in Table 1.

Table -1: Design Parameters

Normal Patch Readings (mm)	
Width(W)	26.08
Length(L)	20
Ground Width (Wg)	35.68

Ground Length (Lg)	29.6
Feed Point Location	(13.04, 17.84)
U Slot Patch Readings (mm)	
Slot Width (D)	22.76
Slot Height (C)	17.07
Height of from Base (H)	1.465
Slot Thickness (E=F)	1.43

4. SIMULATION & RESULT

HFSS software was used to create and simulate this antenna model. The feed point location (13.04, 17.84) yielded the best impedance matching, with a measured impedance of 50.5. The VSWR and Reflection coefficient were also determined to be minimal at this feed point. The performance characteristics of the antenna are shown in Table 2.

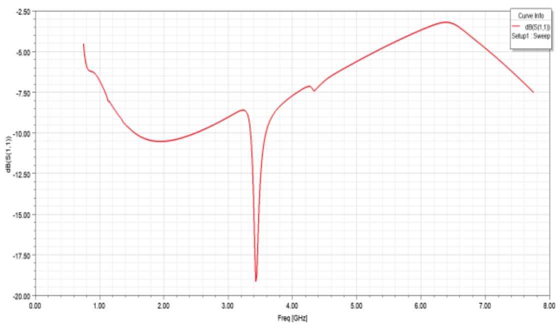

Fig -5: Magnitude of the Reflection Coefficient (dB) and -3dB Bandwidth

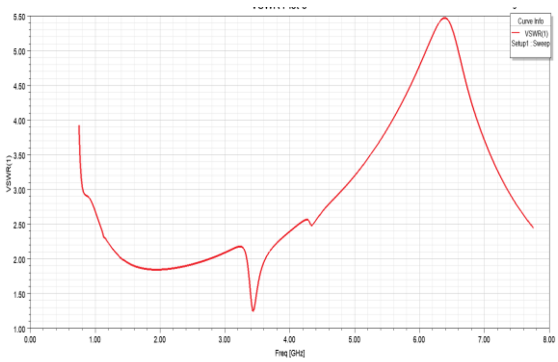

Fig -6: Value of VSWR

Ideally, VSWR must lie in the range of 1-2 which is achieved in our design. The vswr value obtained is between 1 to 1.5 which a good efficiency.

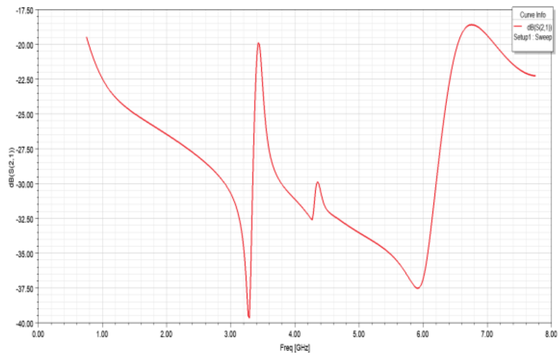

Fig -7: S(2,1) vs Frequency Plot

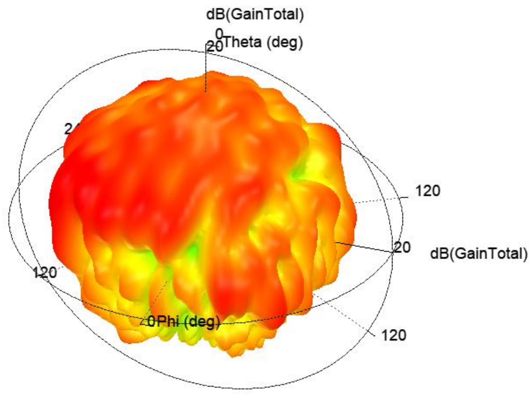

Fig -8: 3D Radiation Pattern.

The above graphs show the plots of several performance parameters. The antenna was discovered to have a gain of 13.8 dBi and be resonating at 3.42GHz. The Reflection coefficient and VSWR values are modest and sufficiently close to optimum values. In the context of patch antennas, the bandwidth of 250 MHz is a good figure.

Table -2: Performance Parameters

Performance Parameters	
Resonance Frequency (GHz)	3.42
Impedance (Ω)	50.5
Reflection Coefficient (dB)	-19.2
Gain (dBi)	13.8
VSWR (absolute value)	1.25
-3 dB Bandwidth (MHz)	250

It can be seen in figure that the optimized model after proper impedance matching can cover the bandwidth from 3.35 to 3.6GHz with return loss less than -10 dB. The feed point location is determined using the formulae to produce the impedance matching, and the right placement point is then found following numerous iterations to reach the value 50.

The isolation between a pair of the antenna elements is more than 20dB.

The simulation with the HFSS software shows the results of radiation in different direction using 3D radiation pattern where the maximum gain that can be seen is 13dBi and the radiation pattern is almost isotropic in nature, which is desired our application.

5. CONCLUSIONS

The performance criteria for the antenna created specifically for the use, 5G application (5G NR N78 Band) at the operating frequency 3.5GHz with the incorporation of U-shaped slot single antenna that was coaxially fed and designed using FR4 substrate material with the height of 1.6mm to realize a 4x4 MIMO antenna are reliable. Furthermore, a good bandwidth is achieved with the least amount of return loss and VSWR.

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