

Directional 2x2 MIMO Microstrip Antenna for LTE 1.8 GHz Application

R P Megantara* and T Hariyadi

Department of Electrical Engineering Education, Universitas Pendidikan Indonesia, Jl. Dr. Setiabudhi No.207, Bandung, Indonesia

*rizkisev@student.upi.edu

Abstract. LTE is a standard of wireless communication access by using GSM/EDGE and UMTS/HSPA technology for high-speed data transfer rates. This technology can download and upload with the speed up to 300 Mbps and 75 Mbps respectively. LTE technology using MIMO system can increase the data rate and capacity on sending and receiving simultaneously on a radio frequency channel so that the antenna which is used for LTE band-3 works at 1.8 GHz also using MIMO structure. In this paper, the authors will propose a MIMO 2x2 antenna with directional radiation patterns that works at LTE band-3 using two types of patches, which are the parasitic and main patch. In this simulation, we use FR-4 as the substrate. This substrate has a dielectric constant of 4.5, and the thickness is 1.6 mm. The method that is used in this research is design and simulation. The calculation, design and simulation process on this research the authors use the CST Studio Suite Software. The target results from this research are the antennas works at 1.8 GHz LTE band; the gain is more than 6 dBi; diversity polarization is vertical and horizontal, coupling between two antennas is less than -20 dB, and the antenna bandwidth is 200 MHz from 1.7 to 1.9 GHz for VSWR less than 2 with directional radiation patterns.

1. Introduction

High demand of data access and communication service in the digital world can be seen from the increase of cell phone and internet usage. Based on the fact above, there is a requirement of a concept that can manage the demand LTE is one of the breakthrough that can solve the problem. LTE is a 4G technology where the Internet Protocol as the transmission medium to transmit Digital Broadband Packages with capacity of 100-300 Mbps [1].

In order to make the technology, antenna is one of the component that is required for the signal transmission with required bandwidth capacity. With this research, the antenna will be designed with the synthesis of other existing concept. Based on the previous study, feeding microstrip slot is one of the antenna construction methods. However, the result of that method has the radiation pattern that spread to all directions [2]. Therefore, the technique used to solve the problem is to make conventional patch so that the radiation pattern will spread to only one direction and the usage of two parasitic patches placed between the main patch to increase the bandwidth capacity [3]. In this paper we propose a directional 2x2 MIMO antenna with polarization diversity using similar method in [3] but for LTE 1.8 GHz application.



2. Antenna Design

In this segment, the antenna construction with CST Studio Suite will be described. Standard bandwidth capacity for LTE band-3 is 1.71 GHz-1.88 GHz with the total bandwidth is 170 MHz [4]. To increase the bandwidth, 2x2 MIMO antenna with two patches design of main and parasitic patch are used [3]. The antenna material used is FR-4 with 4.3 permittivity. The antenna system contains feeding line microstrip with 2x2 MIMO microstrip antenna with rectangular patch. The length of the main patch antenna dimension is around $\frac{1}{2}\lambda$ on FR-4 substrate with λ can be found from equation (1) $\lambda = \frac{c}{f\sqrt{\epsilon_r}}$ [5].

$$\lambda = \frac{c}{f\sqrt{\epsilon_r}} \quad (1)$$

Where,

λ = Wavelength (m)

c = Speed of light (3×10^8 m/s)

f = Center frequency (Hz)

ϵ_r = Substrate permittivity

With using analytical line impedance in CST Studio Suite, the width of feeding line is 3 mm for 50 Ω of impedance.

2.1. Two-element arrays design

For the design of horizontal polarization antenna, two parasitic patches that has smaller dimension compared with main path and coupling placement placed close to the end of the main patch. For the vertical polarization antenna design, two parasitic patches with more or less the same dimension with main patch and coupling placed exactly in fusex = 0.

For the two antenna designs, parasitic patch was placed exactly in the middle and the distance between parasitic and main patch was the same. This is done to avoid the clash of signal from one another. The dimension length in the main patch is $\frac{1}{2}\lambda$ in FR-4 in 1.8GHz frequency with 40mm result, but with optimization of dimension length construction, 38mm result was acquired.

2.2. Microstrip feeding system

System send the signal from the transmitter to element arrays and sent it back from element arrays to the receiver. The microstrip feeding line strip is based on the quarter-wave or $\frac{1}{2}\lambda$ in FR-4. This part make it possible to find a good match in 50 Ω transmitter/receiver with array elements within the vertical and horizontal polarization with the same microstrip feeding line concept [3].

The dimension of Microstrip feeding line can be seen in Table 1. The antenna structure that designed with two FR-4 substrate layers with the same formation structure. Meanwhile, the core of antenna structure is the ground that located within two substrates in which the ground is passed by feeder that connected with the ground that has wider diameter than the feeder. The patch position of antenna transmitter is located above the substrate with the height of 3.2 mm and the feeding line in the lowest layer.

Table 1. Microstrip feeding system.

Parameter	Value (mm)
Substrate Height	1.6
Transformer Width	5.5
Transformer Length	20
50 Ω Line Width	3

2.3. MIMO 2x2 system

Multiple input multiple output (MIMO) communication system is a reliable new technology that provides higher data transmitted via radio frequency. System arrays on the antenna can be used on MIMO technology with the transmitter and receiver of an antenna contained in one device [6]. The 2x2 MIMO antenna design on FR-4 substrate produce a good isolation on reflection coefficient. The final

dimension of 2x2 MIMO antenna is shown by Table 2 and 3. The geometry of 2x2 MIMO antenna can be seen in Figures 1 to 4.

Table 2. The dimension of antenna with vertical polarization.

Parameter	Value (mm)	Parameter	Value (mm)	Parameter	Value (mm)
Lf	3	Ls	80	Ppb	37.15
Lg	80	Ls2	80	Ppk	35.5
Lgr	7	Lsl	5.5	Ps	210
Lpb	42	Lslt	81.5	Ps2	210
Lpb	40	Pf	18.3	Pslt	3
Lpt	3	Pg	210	Tg	0.315

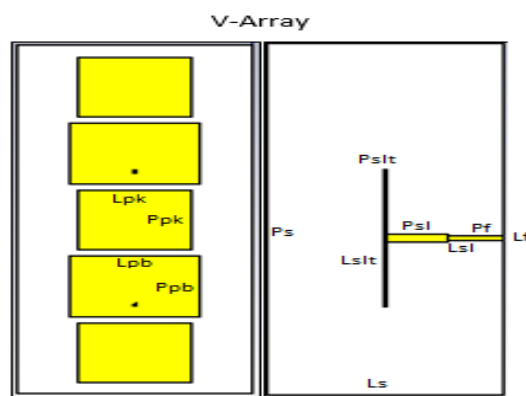


Figure 1. The geometry of antenna with vertical polarization (front and back view).

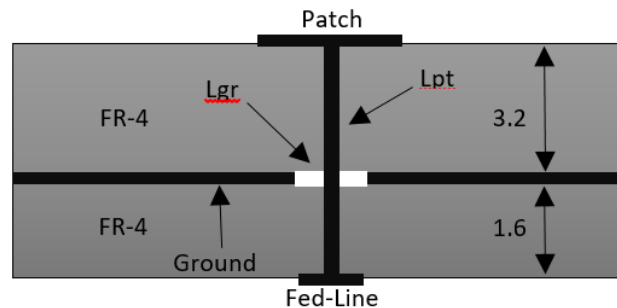


Figure 2. The geometry of antenna with vertical polarization (side view).

Since the stack between the substrate and the ground layer has the same length and width then $P_s = P_{s2} = P_g$ and $L_s = L_{s2} = L_g$. For vertical polarization antenna, the value of the parameter affecting to the operating frequency is P_{pb} . Using equation (1), we obtain the length of P_{pb} that is 40 mm but with the optimization process P_{pb} length is obtained 37.15 mm.

Table 3. The dimension of antenna with horizontal polarization.

Parameter	Value (mm)	Parameter	Value (mm)	Parameter	Value (mm)
Lf	3	Ls	80	Ppb	40
Lg	80	Ls2	80	Ppk	23
Lgr	5	Lsl	5.5	Ps	210
Lpb	37	Lslt	84.5	Ps2	210
Lpb	36.3	Pf	8.5	Pslt	3
Lpt	3	Pg	210	Tg	0.315

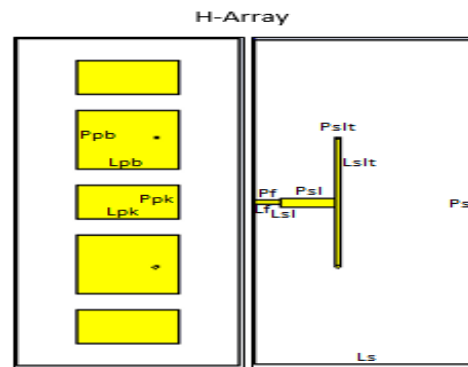


Figure 3. The geometry of antenna with vertical polarization (front and back view).

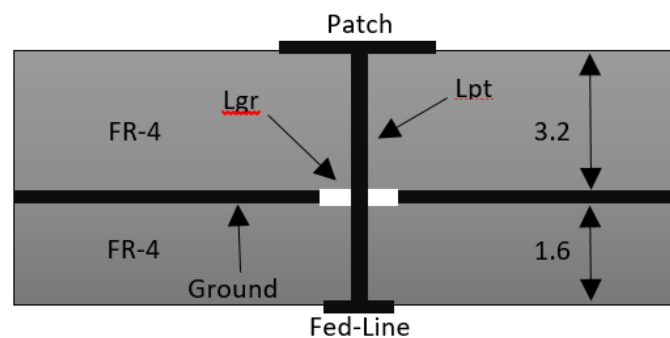


Figure 4. The geometry of antenna with vertical polarization (side view).

Since the stack between the substrate and the ground layer has the same length and width then $P_s = P_{s2} = P_g$ and $L_s = L_{s2} = L_g$. For horizontal polarization antenna, the value of the parameter affecting to the operating frequency is L_{pb} . Using equation (1), we obtain the length of L_{pb} that is 40 mm but with the optimization process L_{pb} length is obtained 37 mm.

The antenna is designed using an electromagnetic coupling technique where there are two substrate layers where the substrate layer on top must be thicker than the substrate layer underneath and between the two substrate layers there is ground [7]. This technique allows more optimal antenna bandwidth.

3. Results and Discussion

The parameters that most affect the operating frequency of the antenna are L_{pb} and P_{pb} . These parameters lead to the achievement of wideband with the expected bandwidth that affects to S-parameters. Four parameters are interrelated because wideband is generated by 2 operating frequencies either the main patch or the parasitic patch. Figure 5 explain how the effect of the P_{pb} parameter on the S-parameters of antenna with vertical polarization. While Figure 6 explain how the effect of the L_{pb} parameter on the S-parameters of antenna with horizontal polarization.

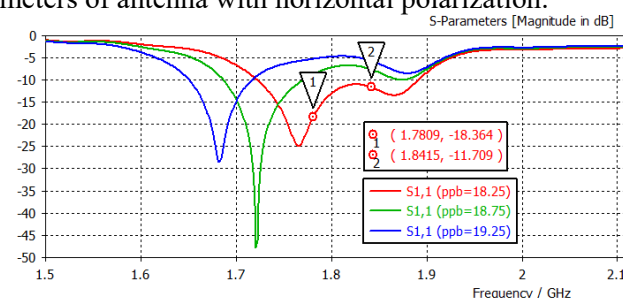


Figure 5. Effect of P_{pb} length to S-parameters of antenna with vertical polarization.

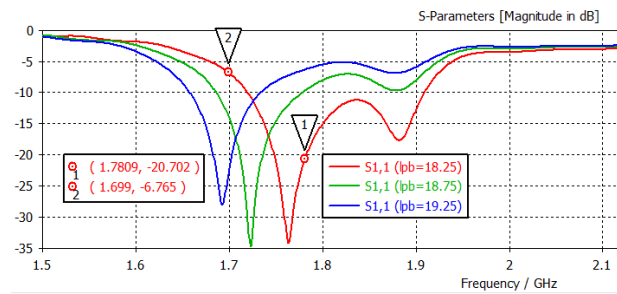


Figure 6. Effect of Lpb length to S-parameters of antenna with horizontal polarization.

From the experiment results Ppb has an effect on return loss of antenna with vertical polarization while Lpb has an effect on return loss of antenna with horizontal polarization. If the value of the two antenna parameters gets larger than the antenna is not suitable, then the optimization process needs to be done. The optimization result of both parameters is 18.25 mm for Ppb and Lpb dimension for good return loss result.

After we obtain the optimal design for both antenna with vertical and horizontal polarization, we design the 2x2 MIMO antenna. Figures 7 show the final design of 2x2 MIMO antenna. The distance between antennas is defined as $\frac{1}{2} \lambda$ where the distance affects the return loss and insertion loss on 2x2 MIMO antenna.

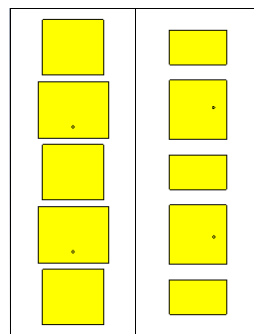


Figure 7. The geometry of 2x2 MIMO antenna.

The simulation goal of 2x2 MIMO antenna is to obtain the return loss as good as each antenna when they are not in MIMO configuration and insertion loss is less than -20 dB [8]. The simulation results show that the bandwidth of the antenna with the horizontal polarization is 1.72 – 1.92 GHz (200 MHz), meanwhile the antenna with vertical polarization is 1.73 – 1.90 GHz (170 MHz) for return loss less than -10 dB. The S-parameters result of 2x2 MIMO antenna can be seen in Figure 8.

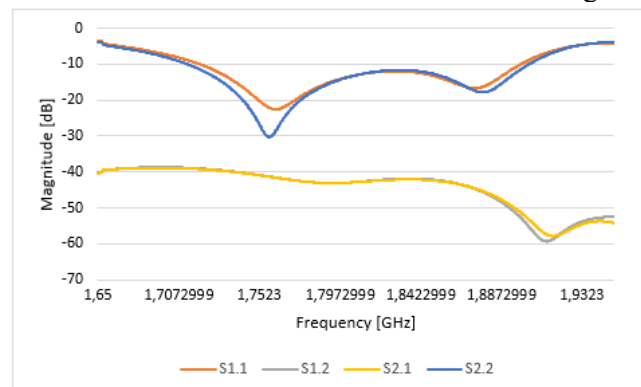


Figure 8. S-parameters result of 2x2 MIMO antenna.

Meanwhile, from the antenna radiation pattern, eventually the result has achieved the required directional radiation pattern with different of antenna gain on each frequency caused by the matching of main and parasitic patch. Tables 4 and 5 show the antenna gain and VSWR was caused by antenna matching.

Table 4. The simulation result of 2x2 MIMO antenna gain.

Frequency (GHz)	Horizontal polarization (dBi)	Vertical polarization (dBi)
1.73	5.718	5.107
1.77	6.418	5.87
1.8	6.373	6.088
1.84	6.206	6.242
1.88	5.062	3.953

Table 5. The simulation result of 2x2 MIMO antenna VSWR.

Frequency (GHz)	Horizontal polarization	Vertical polarization
1.73	1.65	1.8
1.77	1.08	1
1.8	1.3	1.4
1.84	1.7	1.7
1.88	1.4	1.3

The location of the via hole determines the polarization of the transmitted antenna. The location of the via-hole on the antenna with vertical polarization is at $x = 0$ and the location of the via-hole on the is antenna with horizontal polarization is at $x = -10$ with each distance between via-holes is λ . Figure 9 show if the vertical antenna polarization and Figure 10 show if the antenna polarization is horizontal. This is shown by the difference of vector lines formed on the simulation results that can be seen on the surface current.

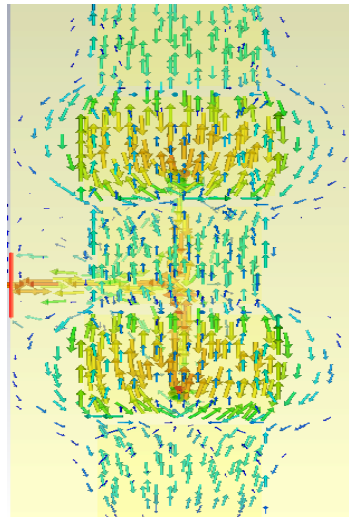


Figure 9. The vector orientation of vertical polarization antenna.

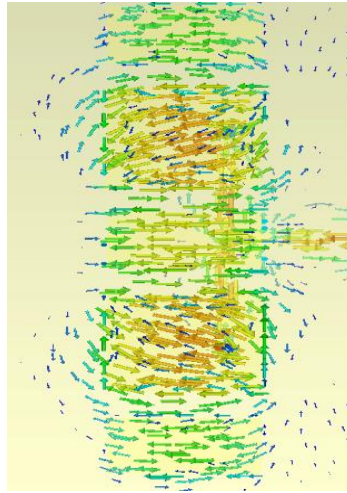


Figure 10. The vector orientation of horizontal polarization antenna.

The radiation pattern of both antennas is directional, but each antenna has different beam width. The beam width of vertical polarization antenna is 45.6 degrees while the horizontal polarization antenna the beam width is 48.2 degrees. The antenna radiation pattern in polar coordinate as shown in Figures 11 and 12.

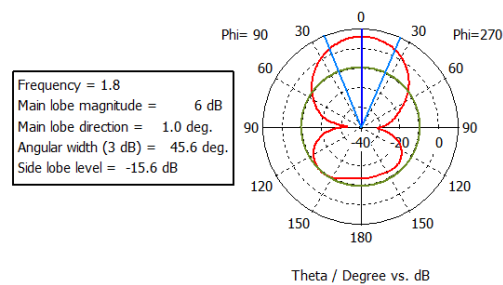


Figure 11. Radiation pattern of vertical polarization antenna.

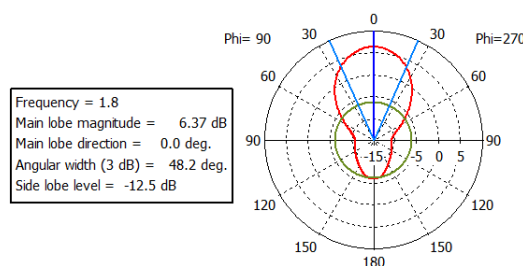


Figure 12. Radiation pattern of horizontal polarization antenna.

4. Conclusions

A 2x2 MIMO antenna with vertical and horizontal polarization has been designed and simulated. This antenna uses FR-4 as substrate with 4.4 permittivity. To enhance the bandwidth, we use coupling feed method that combined with parasitic patch in order to get higher gain. The result from the simulation showed that the antenna operating frequency is 1.73 – 1.90 GHz for the vertical polarization and 1.72 – 1.92GHz for horizontal polarization with gain more than 6 dBi. The simulation results also shown that the mutual coupling of MIMO antenna is very low less than -40 dB. This result can be achieved by using polarization diversity. Regarding this result, this 2x2 MIMO antenna can be implemented for LTE 1.8 GHz application.

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