Low Mutual Coupling Dualband MIMOMicrostrip Antenna Parasitic with Air Gap

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Abstract

Multiple Input Multiple Output (MIMO) systems use multiple antennas at both the transmitter and receiver to improve quality and data rate mobile communication. In recent years, various antennas working on dual or multi bands have been developed. The increasing mutual coupling is one of the negative effect due to the addition of antenna element in MIMO system. This paper presents a low mutual coupling dualband MIMO 2x2 antenna. The proposed MIMO antenna is able to work in dual frequency at 1.8GHz and 2.35GHz. To obtain the optimum design, the characteristic of proposed antenna are numerically investigated through the physical parameters of antenna. By parasitic layer with air gap, mutual coupling can be decreased until 50% and gain of the proposed antenna can be improved until 50%. The obtained results show that proposed antenna has a compact size and a bandwidth of 100 MHz, which is suitable for LTE application.

Keywords: MIMO, mutual coupling, microstrip dualband antenna

1. Introduction

The demand for higher quality and data rate was growing fast in the past few years. One of the most promising solutions to this problem is Multiple Input Multiple Output (MIMO) system [1]. The MIMO technology made a great breakthrough by satisfying the demand of higher quality mobile communication services without using any additional radio resources [1],[2] and it has a significant ability to increase data throughput without additional bandwidth or transmit power (transmitter power). One type of antenna that can be used to increase the channel capacity of MIMO is a microstrip antenna [3]. Various microstrip antennas working on multiband frequency have been developed and reported. In [4]-[6], dual band or tri band antennas have been achieved, but gain of the antennas is not explained. An effective way to obtain dual-band resonant frequency is to use a fractal monopole with a U-shaped slot just like in [7] but the gain remains above 2.0dBi.

Unfortunately, in MIMO system with multiband, mutual coupling is significant issues need to be overcome to enhance the effectiveness of MIMO and it becomes more critical when inter-element spacing is very small. Achieving high isolation between the radiating elements is a challenging task and also it is difficult to control the isolation over the desired bands. This kind of situation can occur in mobile communications, especially in mobile phones, where space limitations become an important variable. Mutual coupling is a function of antenna spacing, number of antennas, and direction of each ray relative to the arrayplane. Hence, it becomes difficult to match the antenna impedance, which is important for efficient energy transfer [2].

In this paper, a compact novel MIMO microstrip antenna works for a dual frequency with low mutual coupling is proposed to be applied for LTE application. The proposed antenna is developed from a triangular microstrip antenna fed by co-planar waveguide (CPW). The development is done by two slots on its triangular patch, a co-planar waveguide feed-line, and parasitic with air gap between the substrate. By air gap between the parasitic antenna allow to increase the gain of the proposed antenna. The numerical design is performed to find the optimum design of antenna where physical parameters of antenna such as length and width of its slots, line width and width of gap in CPW feed, height of the air gap in parasitic layer is investigated intensively through parametrical study.
2. Numerical design of Antenna

The geometry of MIMO (2x2) is based on single patch antenna using two slots with different height for dual frequency operation, co-planar waveguide feed line. Figure 1 illustrates a shape of the single patch dual-band antenna.

Figure 1. Shape of single patch dualband antenna

2.1. Slots of antenna

Basically, the proposed dual-band antenna is modified with add two slots at a single band antenna. Here, the antenna with the frequency resonator is a 1.8 GHz is determined to obtain dual-band antenna. The slot is the most-widely used method to achieve more than one frequency which still maintains the compactness of the antenna [8]-[11]. The proposed antenna deployed on an FR-4 Epoxy substrate with permittivity of 4.3, thickness of 1.6mm and loss tangent (\(\tan \delta\)) = 0.0265. As both the radiating elements and the CPW feeding mechanism are implemented on the same plane; hence, fabrication of the proposed antenna is very easy using a single-sided metallization process.

2.2. Co-planar wave guide (CPW) fed

A CPW fed makes the antenna more suitable for compact wireless communication because of its features like uniplanar structure, easily manufactured and easily integrated with other microwave integrated circuits. Another important advantage of CPW-fed is wider bandwidth than CPS and microstrip line. The 50\(\Omega\) CPW transmission is used to excite the antenna. For the given values of substrate parameters, the CPW dimensions of the CPW line are investigated.

2.3. Parasitic layer with air gap

Several approaches to improving the radiation efficiency and obtaining a high-gain antenna. The electric lens antenna was adapted to achieve a high-gain antenna[12]. However, the commonly used lens antenna is constructed using an expensive crystal material and it is difficult to mount it on the MMIC packet. The technique for improving the radiation efficiency and obtaining a high-gain by arranging parasitic elements above the feeding microstrip antenna elements is examined [13]-[16]. In this paper, to achieve a high-gain, the next step in numerical design of MIMO antenna is employing two parasitic layers. Four patches dual-band element without ground on the first parasitic layer and four patches dual band element with CPW fed on the second parasitic layer.

3. Design of MIMO 2x2 Dual Frequency Antenna

The design is started from the single band-notched characteristic at 1.8GHz and at 2.35 GHz respectively. However, with combination slot pair from the single element antenna, a dual band-notched characteristics antenna is achieved. The slots are carefully tuned so that the antenna can be operable at low and high frequency bands. The dual-band notched characteristic radiator is connected to a 50\(\Omega\) co-planar wave guide (CPW) feed-line.

After a dual-band frequency that is expected the best condition return loss and VSWR, in order to improve gain performance, a triangular patch is placed on the dualband antenna with an air gap between the substrate. The antenna consists of two layers of substrate. The first layer
is a triangular patch only and the second layer consists of triangular patch with CPW fed and a layer of air gap between the two layers of substrate.

The geometry of the MIMO 2x2 dual frequency antenna with CPW is shown in Figure 2. The geometry and configuration of antenna for single-band can be expressed following [1]. The patch antenna is calculated by (1), (2), (3) and (4) for design a microstrip antenna shaped triangular.

\[ f_r = \frac{c k_{r_{\text{max}}}}{2\pi \sqrt{\varepsilon_r}} = \frac{2c}{3 a \sqrt{\varepsilon_r}} \sqrt{m^2 + mn + n^2} \]  

(1)

For mode TM_{10} frequency resonance by the following equation:

\[ f_{10} = \frac{2c}{3 a \sqrt{\varepsilon_r}} \]  

(2)

Where \( a_e \) is:

\[ a_e = \left[ 1 + 2.199 \frac{h}{a} - 12.853 \frac{h}{a \sqrt{\varepsilon_r}} + 16.436 \frac{h}{a e \varepsilon_r} + 6.182 \left( \frac{h}{a} \right)^2 - 9.802 \left( \frac{h}{a \sqrt{\varepsilon_r}} \right)^2 \right] \]  

(3)

And \( a \) is substituted:

\[ a = \frac{2c}{3 f_{10} \sqrt{\varepsilon_r}} \]  

(4)

The antenna is excited by a 50Ω microstrip line. The width of the 50Ω microstrip line is 3 mm, and the gap of the CPW line is \( g = 0.5 \) mm and dimension of ground plane is \( (d_g) = 6.5 \) mm.

Figure 2. The proposed MIMO 2x2 antenna, (a) top view, (b) side view, (c) Front view
For MIMO (2x2) antenna in Figure 2, \( d \) is distance between antenna elements and given by [4]:

\[
d = \frac{\lambda}{4}
\]  

\( (5) \)

4. Simulation Result

Simulation tools have been used to calculate S parameters, based on the Method of Moments. The final optimization, the reflection loss factor vs frequency is depicted in Figure 3. The reflection coefficient is achieved below -21.19 dB at 1.8 GHz and -21.99 dB at 2.35 GHz. The antenna can produce dual band with notch characteristics.

![Simulation result of the dual band MIMO 2x2 Antenna parasitic with air gap](image)

When the number of antenna elements is placed in forming the arrays, mutual coupling between the antenna elements is a critical issue. Mutual coupling is a potential source of performance degradation in the form of deviation of the radiation pattern from the desired one, gain reduction due to excitation of surface wave, increased side lobe levels etc.

Effect of mutual Coupling also occurs in MIMO antenna. One reason is the wave surface. It can change the amount of current, phase, and the distribution of each element so that the overall antenna radiation pattern is different than not having coupling. When the distance between the adjacent elements are not appropriate with equation (2), mutual coupling effects will increase [6].

The mutual coupling simulation at distances of 8 cm is shown in Figure 4. \( S_{21} \) is almost -40 dB at 1.8 GHz and >40 dB at 2.35 GHz, which shows good isolation between antenna elements and it can be seen that the simulation are in a good agreement.

Figure 5 shows the radiation pattern of the dual-band-MIMO 2x2 antenna with CPW fed in \( \theta \) plane. Half-power beam width is 122.0° at frequency of 1.8 GHz, and 97.6° at frequency 2.35 GHz. The main lobe has its peak power at \( \phi \approx 13^\circ \) and at 2.35 GHz, the main lobe has its peak power at \( \phi \approx 166^\circ \).

![The effect mutual coupling Port 1 of Port 2](image)
Low Mutual Coupling Dualband MIMOMicrostrip Antenna .... (Yuli Kurnia Ningsih)

Figure 5. Simulated Radiation Pattern of the dual-band-MIMO 2x2 antenna parasitic with air gap at 1.8 GHz and 2.35 GHz

Figure 6. 3-D Visual of Radiation Pattern of the dual-band-MIMO 2x2 antenna parasitic with air gap at 1.8 GHz and 2.35 GHz

Figure 6 is a 3-D radiation pattern at a frequency of 1.8GHz and 2.35GHz. It can be seen that the antenna radiation pattern is directional which leads only in one direction and direction looks great in the red area. Directivity antenna at a frequency of 1.8GHz is 3.6dBi while the 2.35GHz frequency is equal to 5.3dBi.

The impact of parasitic with air gap is clearly noticeable from Table 2. The improvement of 89% averagely at the desired frequency is due to the fact that the structure of parasitic with air gap providing good isolation characteristics compared to the structure of parasitic without air gap.

Table 2. The effect of parasitic with air gap on mutual coupling and gain

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Parasitic without air gap</th>
<th>Parasitic with air gap</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mutual Coupling</td>
<td>Gain</td>
</tr>
<tr>
<td>1.8GHz</td>
<td>-20.07 dB</td>
<td>3.2 dBi</td>
</tr>
<tr>
<td>2.35GHz</td>
<td>-25.12 dB</td>
<td>2.9 dBi</td>
</tr>
</tbody>
</table>
5. Conclusion
A novel configuration of dual-band MIMO 2x2 microstrip antenna with structure of parasitic with air gap has been studied and simulated. The results of this simulation antenna microstrip for frequency of 1.8GHz shows return loss is -21.19dB with impedance bandwidth about 125MHz and at 2.35GHz shows return loss is -21.99dB with impedance bandwidth about 110MHz. Structure of parasitic with air gap can enhanced the mutual coupling significantly. The result of simulated HPBW is 122° at 1.8 GHz and 97.6° at 2.35 GHz, respectively. It is seen that the gain remains above 3.5dBi in the dual LTE bands. Therefore the proposed antenna is applicable as new candidate for dual frequency antenna to make MIMO in (2x2) antenna microstrip for LTE application in Indonesia.

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