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DESIGN OF LINEAR POLARIZATION ANTENNA FOR WIRELESS MIMO APPLICATION

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ABSTRACT

This paper presents the design of the linear polarized antenna for wireless MIMO communication system. It is impossible to fulfill the demand of the wireless communication system due to limitations in channel capacity on single input single output (SISO) systems. Multiple input multiple output (MIMO) system has become a famous research field for the next generation wireless communication system in order to overcome this problem. Since polarization diversity is effective to avoid the fading loss caused by multipath effects, therefore, polarization diversity becomes one of the most important techniques that can be used to enhance MIMO system performances. It can be utilized to improve the communications channel capacity and utilize the frequency spectrum with frequency reuse technique. Therefore, the development of linear polarized antenna is significant in order to improve the wireless MIMO system performance based on polarization diversity technique. Polarization diversity can be utilized to double the frequency spectrum to realize frequency reuse and improve the communications capacity. This project is to design an antenna that can provide linear polarization to reduce the signal losses.

Keywords: linear polarized antenna, Multiple input multiple output (MIMO) system, wireless.

INTRODUCTION

Antenna plays a crucial role in telecommunication field such as satellite communication, mobile phone and for military use [1]. The growth of mobile communications results in the increasing demand of smart phones, wireless internet and other broadband applications. The demand for high data rate and high capacity are increasing to satisfy the growth of mobile communications [2, 3].

The MIMO technology is become popular nowadays as the demand for high speed; high capacity and high quality transmission in wireless mobile telecommunication are increasing. MIMO technology provide a very high spectral efficient and also increase the channel capacity without extra spectrum by using multiple transmitter and receiver. The loss of spectral efficiency occurs due to the spatial correlation between antennas. In order to decrease the spatial correlation, the spatial diversity is the most common used technology in MIMO system. The distances between MIMO antennas have to be at least half wavelength apart thus larger spacing is required for this technique [3]. MIMO capacity increased proportionally with the number of antennas and thus higher spatial distance between antennas is required [3]. The mutual coupling between antennas occurs due to the narrow space for MIMO antenna design is the critical problem in MIMO system [1]. As a result, the polarization diversity becomes better solution for MIMO system.

In the modern wireless communication, the products such as smart phones and radio frequency identification (RFID) tags are designed in light weight and very compact size. The purpose of compact size and light weight enable the devices to be carried to everywhere. The antenna needs to be designed in a very small size so that the antenna is able to fit inside the compact size products. Moreover, the wireless devices are design to be portable; the antenna designed must be able to fit into the small device and are practical use. Thus, the size of an antenna is also one of the main criteria to take into account when designed the antenna.

DESIGN SPECIFICATION

The antenna is design for the frequency of 2.4GHz, which is useful for the Bluetooth application. The 2.4GHz frequency is an unlicensed band and is free for the public. The antenna is simulating using FR4 board and PEC or copper. FR4 board with thickness of 1.6mm, tangent loss of 0.019S/m and permittivity of 4.4 is used as the substrate. While the PEC with thickness of 0.035mm is used as the conductor.

In this project, the antenna design is targeted to have gain from range of 2dB to 4dB for each of the polarization state. This is to avoid the problem of one of the polarization state provide higher gain and become the dominant mode. The range of the gain is referring to the works of previous researchers. Meanwhile the axial ratio for a circular polarization antenna must be below -2.5dB and for linear polarization antenna must be above -3dB. For this project, the antenna is design to fulfill the compact issue in terms of size by combined the radiator for both polarization states by using 2 ports. The radiation efficiency and the total efficiency for both polarization states must be below -3dB to ensure that the antenna is able to transmit at least 50% of the radiate power respectively. The matching is affect by the total efficiency, as the total efficiency getting closer to positive value the matching is getting better. While for return loss, the result must be below -10dB to ensure that the transmission power of the antenna is more than 90%. The specification of the design is listed at Table-1.

Table-1. Main specification of the design.

Specification	Value
Frequency	2.4GHz
Return loss	<-10dB
Gain	2 - 4dB [42][51][52]
Radiation efficiency	<-3dB
Total efficiency	<-3dB
Multipolarization	Linear polarization
Axial ratio	> 3dB for linear polarization

Antenna design process

The linear polarization antenna is first design to be a rectangular patch. The patch is then added double H-shaped slots. Lastly, the return loss of the design is then improved by adding stair notch to the patch.

Rectangular patch with slots

The rectangular patch is first drawn in CST microwave studio by using PEC (grey colour) and FR4 as the substrate (blue colour). The patch is connected to a CPW fed line. Then the slots are drawn on top of the patch and then substrate the slots from the patch as shown in Figure-1. After the drawing of the patch is done, the setting for the simulation is set as same as the previous design. The effects of the slots dimension are obtained using parametric study method. From previous parametric study, the performance of the design is under performance. Thus, the gap of the ground and CPW fed are studied.

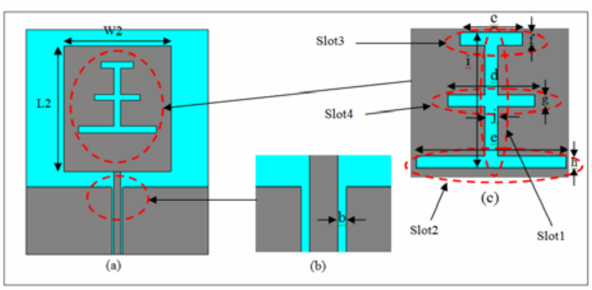

Figure-1. Front view of the rectangular patch with slots.

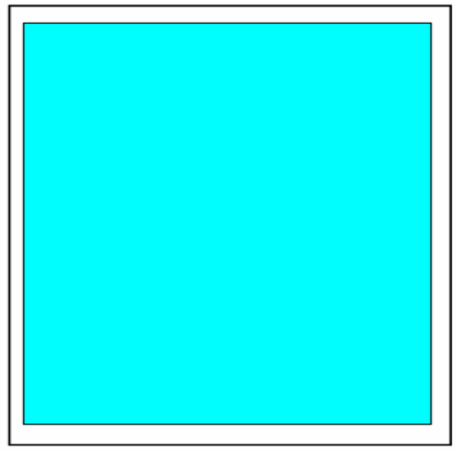

Figure-2. Back view of the rectangular patch with slots.

Table-2. Effects of spacing (b).

b(mm)	**RL**(dB)	**AR**(dB)	**Gain**(dB)
0	-8.57	11.51	0.73
0.1	-9.36	11.57	0.77
0.2	-10.33	11.54	0.66
0.3	-13.98	11.53	0.97
0.4	-15.49	11.55	0.97
0.5	-19.95	11.57	0.96
0.6	-27.74	11.59	0.96
0.7	-17.62	11.63	0.94

From Table-2, the spacing between the CPW fed and the ground has significant effect on the return loss of the design. The return loss start to increase until b = 0.6 mm. In addition, spacing does not affect much on the axial ratio and gain of the design.

Table-3. Effects of slot3 length (c).

c(mm)	**RL**(dB)	**AR**(dB)	**Gain**(dB)
0	-15.61	11.93	1.25
2	-14.56	11.81	1.02
4	-18.64	11.68	0.87
6	-16.65	11.64	0.94
8	-15.14	11.57	1.01
10	-13.73	11.52	1.05

The parameter of c does not affect much on the axial ratio and gain of the antenna as shown in Table-3. However, the axial ratio of the antenna is decreasing as the c increasing. While for the return loss of the antenna is unstable when the c is increased.

Table-4. Effects of slot4 length (d).

d(mm)	**RL**(dB)	**AR**(dB)	**Gain**(dB)
0	-15.61	11.93	1.25
2	-14.85	11.85	1.08
4	-18.74	11.81	0.91
6	-16.83	11.85	1.02
8	-15.37	11.78	1.09
10	-13.98	11.71	1.11

Slot 4 length, *d* does not affect much on axial ratio and gain of the design. For return loss of the design, it did not have a stable trend as the d increased.

Table-5. Effects of slot2 length (e).

e(mm)	**RL**(dB)	**AR**(dB)	**Gain**(dB)
0	-15.61	11.93	1.25
2	-14.63	11.79	1.02
4	-18.69	11.87	0.86
6	-16.63	12.01	0.98
8	-15.21	11.91	1.01
10	-13.85	11.86	1.09

From Table-5, the return loss of the design do not showed a stable pattern. The return loss slightly increased after e=4mm. Furthermore, axial ratio and gain of the design do not affect much by the slot 2 length. The gain only differs around 0.2 dB.

Table-6. Effects of slot3 width (f).

f(mm)	**RL**(dB)	**AR**(dB)	**Gain**(dB)
0	-17.88	11.63	0.93
0.5	-18.36	11.64	0.99
1	-18.59	11.64	1.02
1.5	-18.76	11.64	1.03
2	-18.77	11.63	1.03

The width of slot 3, f does not affect much on the gain of the design. The return loss of the design decreased when the width getting wider. But the axial ratio remains the same as the slot3 width increasing. The gain is still smaller even the slot3 width increasing.

Table-7. Effects of slot4 width (g).

g(mm)	**RL**(dB)	**AR**(dB)	**Gain**(dB)
0	-16.11	11.81	1.06
0.5	-16.54	11.82	1.12
1	-16.76	11.85	1.18
1.5	-16.74	11.86	1.18
2	-16.68	11.87	1.18

As shown in the Table-7, width of slot 4 did not affect much on the axial ratio, gain and return loss. But still the gain is getting better as the width increasing. The axial ratio of the design is still a linearly polarized antenna.

Table-8. Effects of slot2 width (h).

h(mm)	**RL**(dB)	**AR**(dB)	**Gain**(dB)
0	-16.47	11.79	1.02
0.5	-16.75	11.84	1.10
1	-17.01	12.02	1.13
1.5	-16.79	12.04	1.17
2	-16.58	12.05	1.18

From Table-8, the results showed that the width of slot2 does not affect much on the return loss, axial ratio and gain of the design. As the width of slot2 increase, the gain is only increased from 1.02dB to 1.18dB. The axial ratio is also increased around 0.26dB from 11.79dB to 12.05dB.

Table-9. Effects of slot1 length (i).

i(mm)	**RL**(dB)	**AR**(dB)	**Gain**(dB)
2	-19.18	9.00	5.19
4	-18.77	8.99	5.23
6	-19.11	8.98	5.18
8	-18.94	9.03	5.21
10	-16.72	8.79	5.31

As the slot1 length increasing, the return loss is slightly increased. However, the gain is only decreased a bit from 5.37dB to 5.21dB. In addition, the axial ratio is increased around 0.2dB and the antenna is still a linearly polarized antenna.

Table-10. Effects of slot1 width (j).

j(mm)	**RL**(dB)	**AR**(dB)	**Gain** (dB)
0	-15.61	11.93	1.25
1	-12.33	11.89	0.79
2	-12.21	11.87	0.95
2.5	-11.83	12.09	1.04

As the slot1 width increased, the return loss is increasing. While for the gain of the design is decreasing as the width of slot1 increasing. The axial ratio of the design is increasing from 11.93dB to 12.04dB.

RESULT AND DISCUSSIONS

The final design of linear polarization antenna consists of a rectangular patch with double H-shaped slots and the design is added with stair notches. Figure-3 and Figure-4 are the front view and back view of the linear polarization final design antenna. Table-9 is the optimum dimensions of the linear polarizes antenna.

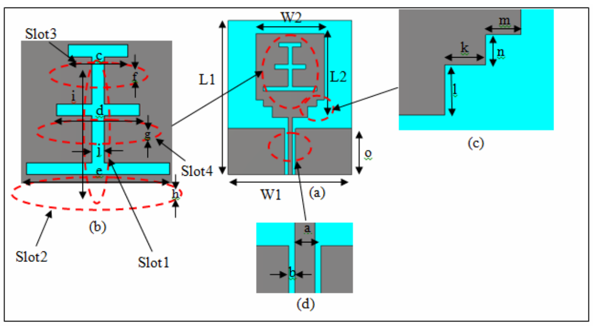

Figure-3. Front view design of final linear polarization antenna.

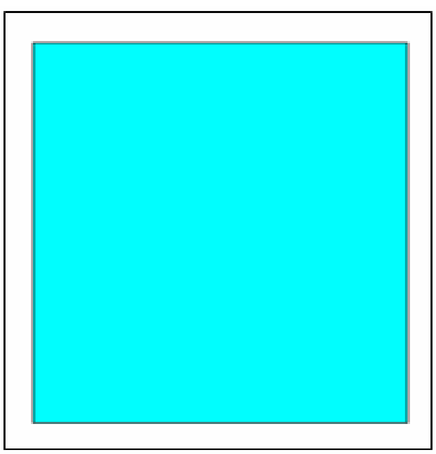

Figure-4. Back view design of final linear polarization antenna.

Table-11. Optimum dimension of linear polarization antenna.

	Value(mm)		**Value**(mm)		**Value**(mm)
L1	35	d	7	j	1
W1	28	e	12	k	3.7
L2	19	f	1	l	2.5
W2	15.4	g	1	m	1.7
A	1	h	1	n	1.5
B	0.7	i	11	o	10.5
C	5				

Figure-5, Figure-6 and Figure-7 are the comparison graphs of return loss, axial ratio and gain between the rectangular patch, rectangular patch with slots and rectangular patch with slots and notches. The return loss is improved with the used of notches from -8.9dB at frequency of 2.398GHz to -38.7dB at frequency of 2.401GHz. However, the gain of the patch with slots and notches is decreased from 2.16dB to 1dB. The axial ratio of these three antennas is all linear polarized antennas. The return loss is improved with slots and notches, but the gain is degraded.

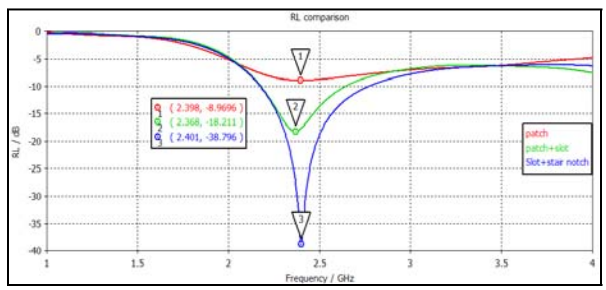

Figure-5. Return loss comparison.

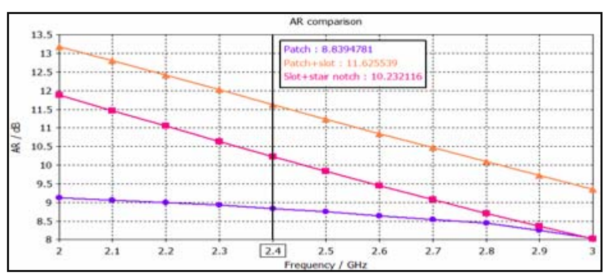

Figure-6. Axial ratio comparison.

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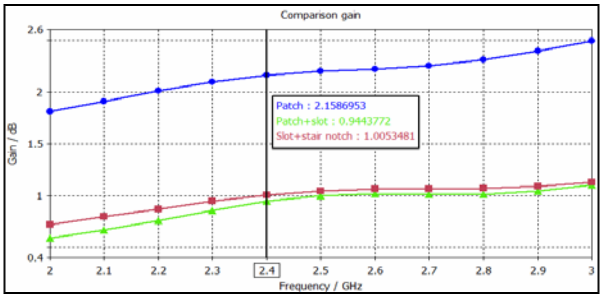

Figure-7. Gain comparison.

Figure-8 is the comparison of return loss between the measurement and the simulation for linear polarized antenna. The measured return loss consists of ripple at the front and the end of the response. The bandwidth of the measured return loss is much wider than the simulation.

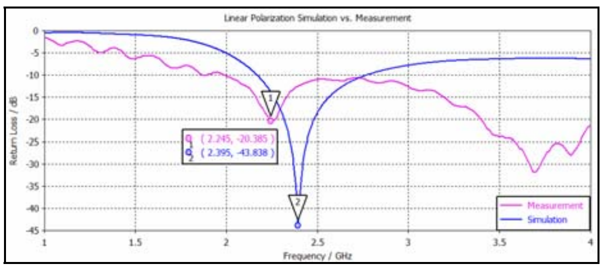

Figure-8. Return loss comparison for simulation and measurement (linear polarization).

Figure-9 is the radiation pattern for linear polarization in terms of vertical and horizontal orientation. The simulated radiation pattern for vertical is an ‘8’ shape, however the measured radiation pattern is more like a circle shape. While, the radiation pattern for horizontal orientation, the shape of the measured radiation pattern is almost the same with simulated radiation pattern.

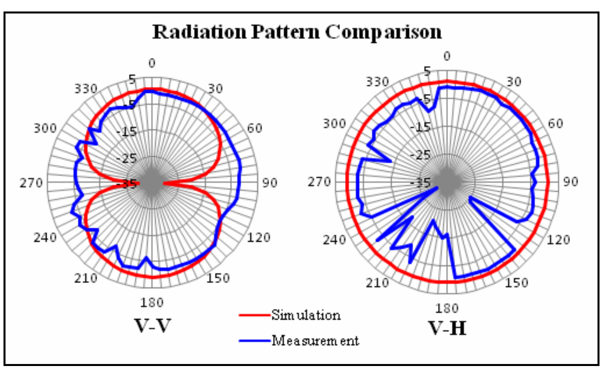

Figure-9. Radiation pattern comparisons for linear polarization.

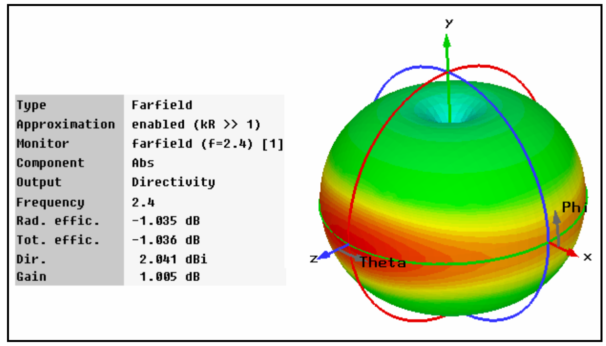

Figure-10. Gain and directivity.

CONCLUSIONS

This paper presents the design of Linear Polarization for wireless MIMO communication system. Wireless channel capacity seems very important nowadays in order to support the broadband applications. Then, the design of linear polarized antenna has been done. Rectangular patch with slots technique been discussed. The linear polarized antenna can be used in developing the polarization diversity in wireless MIMO communication system.

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