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Design of Multiband MIMO 2 x 2 Microstrip Antenna with Multi-slot Method

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Abstract

An MIMO antenna is multiple antenna that can be applied at same time simultaneously, because MIMO antennas can increase system capacity. One type of antenna used for wireless communication is a microstrip antenna. As novelty of this research, slot method was used to get frequency according to MIMO 2x2 specification and method to increase system capacity on microstrip antenna. The antenna is simulated using Advanced Design System 2009 software (ADS 2009), then fabricated using FR4 substrate with $\varepsilon_r = 4{,}3$, $\tan\delta = 0{,}0265$, h = *1,66 mm*, and be measured with Vector Network Analyzer (VNA). The design results have a performance that is f_c (single / MIMO 2x2) had value of f_1 0.9 GHz / 0.9 GHz, f_2 1.8 GHz / 1.8 GHz, f_3 2.4 GHz / 2.38 GHz, f_4 3.5 GHz / 3.52 GHz, and f_5 3.8 GHz / 3.79 GHz. A simulated result is very good agreement with measured result.

Keywords: Multiband Antena, MIMO, Microstrip.

INTRODUCTION

The development of mobile communications is also continuously supported by adequate devices. Antenna is a tool that is very attached to the wireless communication system. Antenna which has a simple design and can operate on many bands for wireless communication systems has been thoroughly researched and developed extensively. Antenna has several advantages such as small size, low cost production and simple [1].

The development of technology of communication system always produces new technology. The technology must be supported by high-speed data service (high *data rate*) and has a reliable Quality Of Service (QOS). The current emerging technology is wireless technology that allows users to move around. Multiple Input Multiple Output (MIMO) antennas are antennas that can be applied today, because MIMO antennas can increase system capacity [2].

The focus of the world today is the use of a MIMO system. The MIMO system provides high data rates, large capacity and provides good spectrum utilization for a communication channel [3]. MIMO system works better when the correlation between multipath signals is less. This can be obtained on the antenna system by introducing various method differences at the antenna design level. Different method on this antenna system will really improve MIMO performance [4].

The research on microstrip antenna has been done by some previous researcher, either research which only make multiband microstrip antenna, MIMO antenna design, or combination of both. The research design of MIMO 2x2 quinband microstrip antennas for GSM, LTE, WLAN, and WiMAX applications refers from some previous research.

In 2012 Masoumeh Darvish [5] conducted a research which was multiband uniplanar monopole antenna for MIMO applications. The antenna was proposed to work at frequencies of 2.4, 3.5, and 5.5 GHz with respective bandwidths of 56, 41, 111 MHz and mutual coupling values less than -19 dB. In 2013 Chandra Elia [6] conducted the research of designing a dual-band rectangular slot microstrip antenna (2.3 GHz and 3.3 GHz) with proximity coupled batching. In this study, microstrip antenna with square-shaped patch with proximity coupled proximity is the result of a Dual-Band microstrip antenna at working frequency 2,29-2,39 GHz and 3,29-3,39 GHz using FR4 substrate.

Subsequent research in 2013 Fitri Yuli Zulkifli [7] conducted a research which was active integrated microstip MIMO antenna for gain enhancement. With a bandwidth impedance of 191 MHz and also S21 value of -35 dB. Subsequent research in 2014, Songsong Xiao [8] conducted the study of a compact dual-band microstrip MIMO antenna for LTE mobile terminals. The antenna operates at a frequency of 2.6 GHz with a bandwidth of 50 MHz and a frequency of 3.7 GHz with a bandwidth of 200 MHz and a mutual coupling value of less than -16 dB. The purpose of this paper is to design the quadband antenna that is at 0.9 GHz band for GSM900, 1.8

GHz for LTE, 2.4 GHz for WLAN, 3.5 GHz for Wimax, 3.8 GHz for WLAN 3.8, and to make the antenna into a MIMO system.

MULTIBAND MIMO ANTENNA

A subsystem of wireless transceiver consists of oscillator [9], band-pass filter (BPF) [10][11][12][13], low noise amplifier (LNA) [14], and antena [15]. Microstrip antenna with slot method is a modified form of basic geometry of microstrip patch antenna form, theoretically most form of microstrip patch can be given slot (slot). Here is a slot form on the microstrip patch antenna [1].

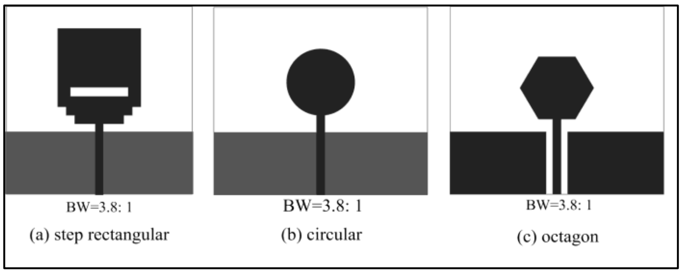

Figure 1: Microstrip slot antenna

Multiple input, Multiple output (MIMO) MIMO is an antenna technology for wireless communication where there are several antennas used in the source (transmitter) and destination (receiver). The antennas at each end of the communication circuit are combined to minimize errors and optimize data rates. MIMO is one of several forms of smart antenna technology, others have MISO (Multiple input, Single output) and SIMO (Single input, Multiple output). In conventional wireless communications, one antenna is used at the sender and one antenna is used at the receiving end. In some cases, this poses a problem because of the multipath effect. When an electromagnetic field (EM Field) encounters obstacles such as hills, valleys, buildings, and utility cables, these waves will be scattered across multiple lines, causing signal delays or signals not to be received at the same time and causing problems such as faded data / graphics, cut-out (cliff effect), and intermittent acceptance (acceptance of a piece). In digital communication systems such as wireless Internet, it can lead to decreased data transmission speed and error increase [1]

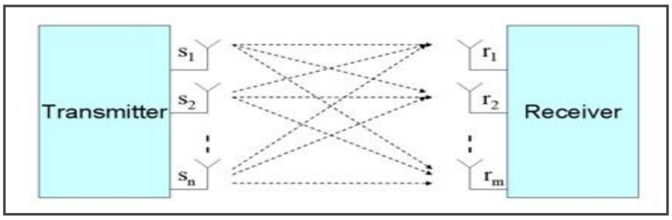

Figure 2: MIMO System Model [1]

The use of two or more antennas, allow for transmission of multiple signals at once and reduce or eliminate the possibility of missing or delayed signals due to this multipath effect. MIMO technology is also used in digital TV, WLAN, and mobile phone communications [1].

DESIGN OF MULTIBAND MIMO ANTENNA

The following is the design stage of quinband microstrip antenna with slot method and MIMO 2x2:

a. Specify the specification

The first thing to do is to determine the antenna specification to be made such as f1 = 0.9 GHz, f2 = 1.8 GHz, f3 = 2.4 GHz, f4 = 3.5 GHz, f5 = 3.8 GHz, BW≥50 MHz.

b. Determining the type of substrate

Substrart used was FR4 with $\varepsilon_r = 4{,}3$, $\tan\delta = 0{,}0265$, h = 1,66 mm..

c. Calculation of dimensions and simulations

The dimension calculations use the equations to determine the antenna's initial shape manually and simulation using the Advanced Design System 2009 software to determine the initial frequency of the antenna.

d. Modification to obtain quinband frequency

Antenna Modification using softwareAdvanced Design System 2009 to make the antenna get quinband frequency according to specification.

e. MIMO 2x2

MIMO is an antenna technology in which multiple antennas are combined into one to minimize errors and optimize data rates [1], in a study using the 2x2 MIMO method.

f. Antenna fabrication

The antenna fabrication was conducted by converting the simulation result to visio format then sent it to the microstrip antenna fabrication place to get the physical result of the microstrip antenna.

g. Measurement of antenna

Measuring the specifications of microstrip antennas fabricated was performed by using Virtual Network Analyzer.

h. Analyze the results

Analyze the results from the simulation data and compare with the measurement data

Calculation of patch dimension was conduced to get 900 MHz frequency using equation as follows:

The following equation is used to get the width [1]

$$W = \frac{c}{2fo\sqrt{\frac{\varepsilon r+1}{2}}} \qquad (3.1)$$

$$W = \frac{3 \times 10^8}{2 \times 1800\sqrt{\frac{4,3+1}{2}}}$$

$$W = 51,1\ mm$$

The following equation is used to get the value of ε_{eff} [1]:

$$\varepsilon_{eff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left|\frac{1}{\sqrt{1+12\left(\frac{h}{w}\right)}}\right| \quad (3.2)$$

$$\varepsilon_{eff} = \frac{4,3+1}{2} + \frac{4,3-1}{2}\left|\frac{1}{\sqrt{1+12\left(\frac{1,6}{0,0265}\right)}}\right|$$

$$\varepsilon_{eff} = 2,843$$

The following equation is used to get he length [1]:

$$L = \frac{c}{2fo\sqrt{\varepsilon_{eff}}} \quad (3.3)$$

$$L = \frac{3 \times 10^8}{2 \times 1800MHz\sqrt{2,843}}$$

$$L = 49,4\ mm$$

From the equation above it was obtained the value of length (L) = 49.4 mm and width (W) = 51.1 mm for 1800 MHz frequency. Figure 3 is a microstrip antenna design prior to the slot method

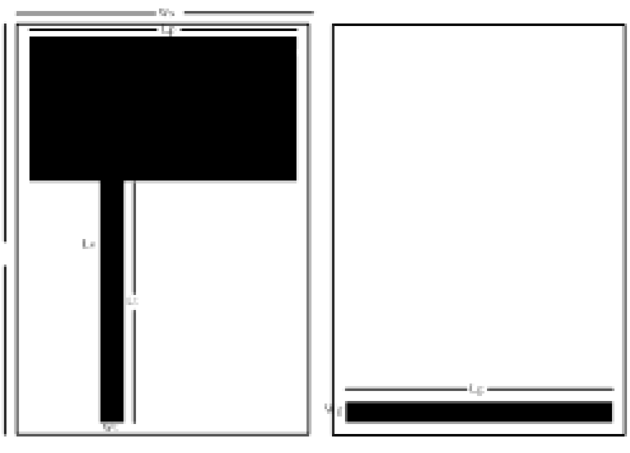

Figure 3: Microstrip Antenna Design

Figure 3 shows the basic design of microstrip antenna, patch antenna is rectangular and has long transmission line. Here is a microstrip antenna specification.

Table 1: Microstrip Antenna Specification

Parameters	L (mm)
ground length (Lg)	44
Ground width (Wg)	3.5
substrate length(Ls)	68
Substrate width (Ws)	48
Patch length (Lp)	44
Patch width (Wp)	24
Transmission path length (Lt)	40
Transmission path width (Wt)	4

From the specification in Table 1 during simulation the following results are obtained.

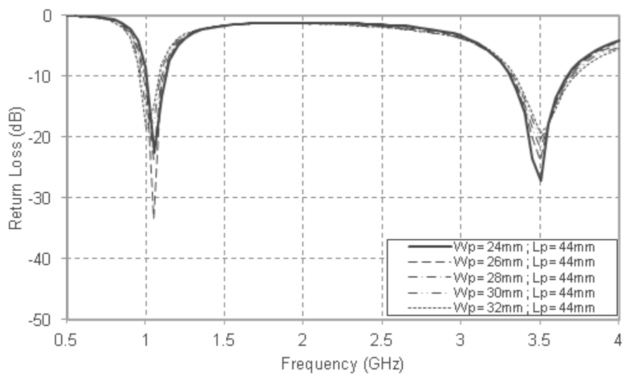

Figure 4. *Return Loss* Chart of Microstrip Antena

Figure 4. represents the return loss graph of the microstrip antenna transmission line iteration. The Y axis represents the return loss from the range 0 dB to -40 dB, whereas the X axis is the frequency of the range 0.5 GHz to 4 GHz. At the first iteration Wp = 24 mm and Lp = 44 mm frequencies are at 1.05 GHz and 3.50 GHz respectively -23 dB and -27 dB, the second iteration Wp = 26 mm and Lp = 44 mm the frequency is at 1.05 GHz and 3.50 GHz respectively -33dB and -23 dB, the third iteration Wp = 28 mm and Lp = 44 mm frequencies are at 1.05 GHz and 3.50 GHz respectively -23 dB and -22dB, the fourth iteration Wp = 30 mm and Lp = 44 mm frequency are at 1.05 GHz and 3.50 GHz respectively -17dB and -20dB, the fifth iteration Wp = 32 mm and Lp = 44 mm the frequency is at 1 , 05 GHz and 3.50 GHz respectively -18dB and -19dB respectively. At iteration there was a change of resonance value at frequency 1 of -23dB, -33dB, -23dB, -17dB, -18dB, frequency 2 from -27dB, -23dB, -22dB, -20dB, -19dB, So that it was taken the best iteration that is at resonance -23dB and -27dB with bandwidth of 50 MHz and 100 MHz but still not getting quinband frequency.

The antenna in Figure 3. only generates 2 frequencies of 1.05

GHz and 3.50 GHz. It still needs a second frequency that is 2.4 GHz, therefore to meet the quinband antenna specification is done slot method on patch antenna. Figure 3.4 is a microstrip antenna design with slot method

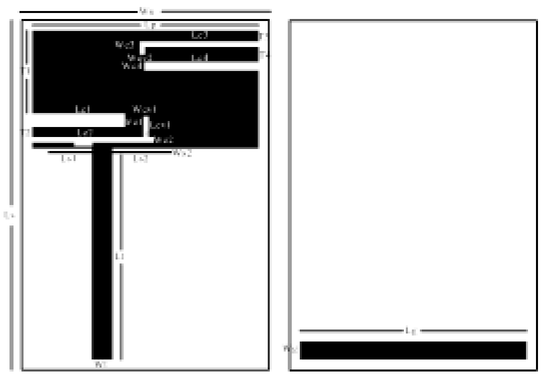

Figure 4: Microstrip antenna design with slot method

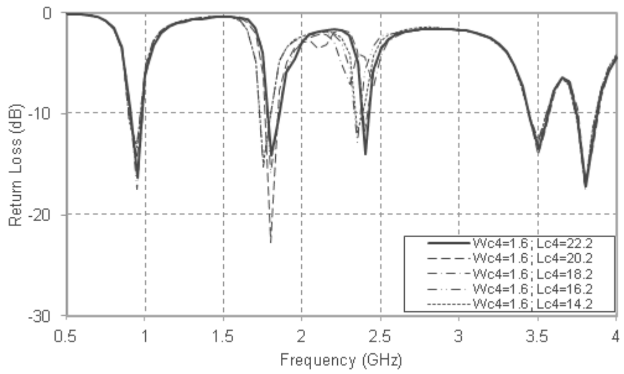

Figure 5: Return Loss Chart of Quinband Microstrip Antenna

Figure 5 is a return loss graph of the slot 6 iteration on the quinband microstrip patch antenna. Y axis represents the return loss from the range of 0 dB to -30 dB, whereas the X axis is the frequency from the range 0.5 GHz to 4 GHz. In the first iteration Wc4 = 1.6 mm and Lc4 = 22.2 mm frequencies were at 0.95 GHz, 1.8 GHz, 2.4 GHz, 3.5 GHz, 3.8 GHz, the second iteration Wc4 = 1.6 mm and Lc4 = 20.2 mm frequencies were at 0.95 GHz, 1.8 GHz, 2.4 GHz, 3.5 GHz, 3.8 GHz, the third iteration Wc4 = 1.6 mm and Lc4 = 18.2 mm frequencies were at 0.95 GHz, 1.75 GHz, 2.3 GHz, 2.45 GHz, 3.5 GHz, 3.8 GHz, the fourth iteration Wc4 = 1.6 mm and Lc4 = 16.2 mm frequencies were at 0.95 GHz, 1.8 GHz, 2.35 GHz, 3.5 GHz, 3.8 GHz, fifth iterations Wc4 = 1.6 mm and Lc4 = 14.2 mm frequencies were at 0.95 GHz, 1.75 GHz, 2.35 GHz, 3.5 GHz, 3.8 GHz. At this time iteration of change tends to occur in the third iteration where there was a shift in the frequency of 2.4 GHz and the emergence of new frequencies, although not resonate, the 4th iteration to 3 frequency shifted to 2.35 GHz and at the 5th iteration of the 2nd frequency shifted to 1.75 GHz . From the above iterations the best iterations are taken with the first iteration with Wc4 = 1.6 mm and Lc4 = 22.2 mm at the frequencies of 0.95 GHz, 1.8 GHz, 2.4 GHz, 3.5 GHz, 3.8 GHz

The antenna of Fig. 5 conforms to the frequency specification with quinband frequency but allows for the transmission of multiple signals at once and reduces or eliminates the possibility of missing or delayed signals due to multipath effect therefore the quinband microstrip antenna was MIMO2x2 method. Figure 6 is a microstrip antenna design with slot method and MIMO 2x2.

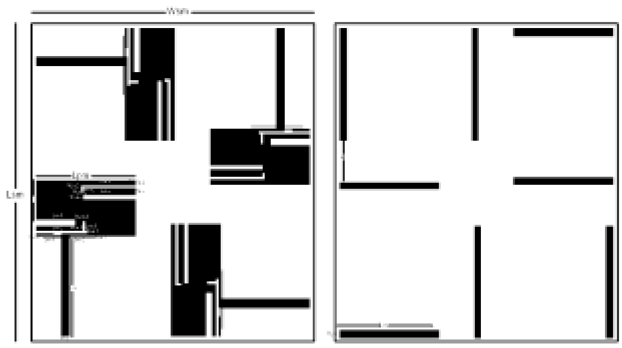

Figure 6: Antenna Design with Slot and MIMO 2x2

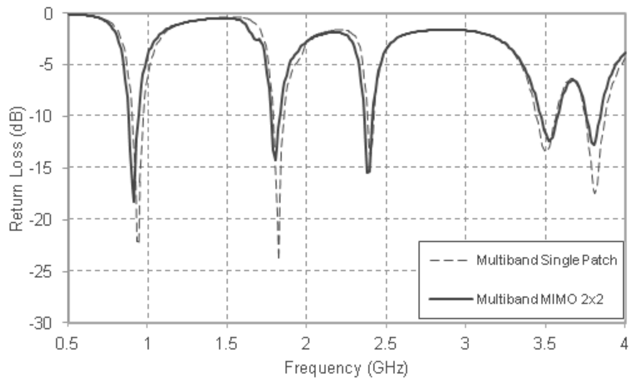

Figure 7: Graphic Return Loss of Quadband MIMO 2x2 Quinband Microstrip Antenna

Figure 7 is a graph of return loss from microstrip antenna simulation slot and MIMO 2x2 method. Y axis represents the return loss from the range 0 dB to -30 dB, whereas the X axis is the frequency from the range of 0.5 GHz to 4 GHz. Microstrip antenna with slot method and microstrip antenna with slot method and MIMO 2x2 has 5 frequency which was at frequency of 0.9 GHz, 1.8 GHz, 2.4 GHz, 3.5 GHz and 3.8 GHz, but used for this research only 3 frequency which was 1.8 GHz, 2.4 GHz , and 3.5 GHz. In microstrip antenna with slot method had frequency of 0.93 GHz, 1.82 GHz, 2.4 GHz, 3.5 GHz, and 3.81 GHz, microstrip antenna slot method with MIMO 2x2 has frequency of 0.91 GHz, 1.8 GHz, 2.38 GHz, 3.52 GHz, and 3.8 GHz. Bandwidth of each microstrip antenna frequency with slot was 40 MHz, 40 MHz, and 90 MHz whereas microstrip antenna with slot and MIMO 2x2 are 40 MHz, 50 MHz, and 100 MHz.

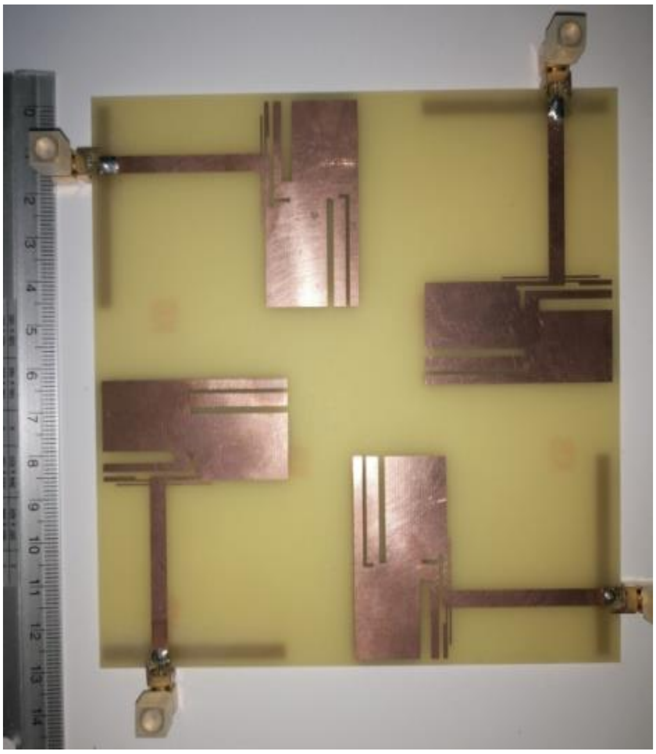

Figure 8: Realization of Microstrip Antenna using Slot and 2x2 MIMO Method

Figure 9 is a graph of return loss from simulation and quinband microstrip antenna measurement before and after MIMO 2x2 method. The Y axis represents the return loss from the range 0 dB to -60 dB, whereas the X axis is the frequency of the range 0.5 GHz to 4.5 GHz. During simulation before MIMO 2x2antena microstrip method operates at frequency 0.9 GHz, 1.8 GHz, 2.4 GHz, 3.5 GHz, and 3.8 GHz at return loss -24.217 dB, -24.216 dB, -14.014 dB, -13.433 dB, and -17.494 dB, and when the measurement before MIMO 2x2antena microstrip method operates at the frequency of 0.56 GHz, 1.8 GHz, 2.45 GHz, 3.63 GHz, and 4 GHz at the return loss -22.795 dB, -15.382 dB, -9.119 dB, -7.476 dB, and -22.98 dB, while during simulation after MIMO 2x2 method the microstrip antenna operates at frequency 0.9 GHz, 1.8 GHz, 2.38 GHz, 3.52 GHz, and 3.79 GHz at return loss -18.386 dB, -14.203 dB, -15.797 dB, -12.353 dB, -12.716 dB, and when the measurement after MIMO 2x2 method the microstrip antenna operates at a frequency of 0.55 GHz, 1.75 GHz, 2.42 GHz, 3.65 GHz, and 4.01 GHz at return loss -35.837 dB, -23.594 dB, -8.491 dB, -9.912 dB, and -39.2 dB.

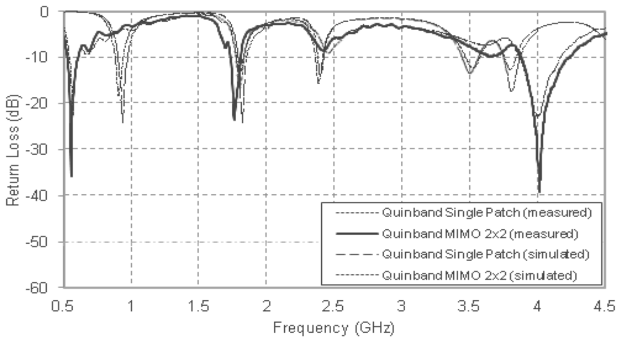

Figure 9: Graph of Return Loss Quinband Antenna

The bandwidth of each frequency of the microstrip antenna at the simulation is 64.5 MHz, 58 MHz, 39 MHz, 116 MHz, 126 MHz, 58.5 MHz, 48 MHz, 51 MHz, 103 MHz, and 84 MHz while the measurement is 90 MHz, 50 MHz , 60 MHz when the return loss at -8dB, 140 MHz when the return loss at -7 dB, 310 MHz, 80 MHz, 70 MHz, 40 MHz when the return loss at -7dB, and 240 MHz when the return loss value at - 8, 350 MHz. At frequency 1 there is a frequency shift from 0.9 GHz to 0.56 GHz, in frequency 2 fixed at 1.8 GHz, in frequency 3 there is a shift from 2.4 GHz to 2.45 GHz and decreased return loss, 4 shifted and decreased return loss so the resonant becomes less resonant, while the frequency 5 shift from 3.8 GHz to 4 GHz at the time before the antenna is MIMO 2x2 method, whereas after the antenna is done MIMO 2x2 frequency 1 shift from the frequency of 0.9 GHz to 0.55 GHz, from 1.8 GHz to 1.75 GHz, in frequency 3 there is a shift from 2.38 GHz to 2.42 GHz and there was a decrease in return loss, the frequency 4 shift from 3.52 GHz to 3.65 GHz and there is a decrease in return loss value, whereas at the 5th frequency there is a shift from 3.79 GHz to 4.01 GHz.

CONCLUSIONS

This research was proposed slot method was used to get frequency according to MIMO 2x2 specification and method to increase system capacity on microstrip antenna. The antenna is simulated using Advanced Design System 2009 software (ADS 2009), then fabricated using FR4 substrate with $\varepsilon_r = 4{,}3$, $\tan\delta = 0{,}0265$, $h = 1{,}66\ mm$, and be measured with Vector Network Analyzer (VNA). The design results have a performance that is f_c (single / MIMO 2x2) had value of f_1 0.9 GHz / 0.9 GHz, f_2 1.8 GHz / 1.8 GHz, f_3 2.4 GHz / 2.38 GHz, f_4 3.5 GHz / 3.52 GHz, and f_5 3.8 GHz / 3.79 GHz. A simulated result is very good agreement with measured result.

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REFERENCES

[1] Constantine. A. Balanis, "Antenna Theory: Analysis and Design", (USA: John Willey and Sons, 1997).

[2] Goldtri Lumban Gaol, "Design and Realization of 3x3 MIMO Microstrip Antenna at Frequency 2,6-2,7 GHz", Thesis, Telkom University, 2014.

[3] Arny Adila Salwa Ali and Sharlene Thiagarajah, "A Review on MIMO Antennas Employing Diversity Techniques". Proceedings of the International Conference on Electrical Engineering and Informatics Institute of Technology Bandung, Indonesia. June 17-19, 2007.

[4] Rafelly Jhon, "Design and Realization of MIMO Bowtie 4x4 Microstrip Antenna at Frequency 1.8 GHz for LTE Applications.", Journal of Eproc, PP. 1-8. Telkom University, 2013.

[5] Masoumeh Darvish, "Multiband Uniplanar Monopole Antenna for MIMO Applications", Iranian Conference on Electrical Engineering (ICEE), PP.1125-1128. Tehran, Iran, 2012.

[6] Chandra Elia Agustin Tarigan, "Designed Antenna Microstrip Rectangular Dual-Band Slot (2.3 Ghz and 3.3 Ghz) with Proximity Coupled Batching", Singuda Ensikom, Vol.11 No.31, PP. 112-117. University of North Sumatra, 2015.

[7] Fitri Yuli Zulkifli, "Active Integrated Microstrip MIMO Antenna for Gain Enhancement.", COMNETSAT, PP. 37-40. Depok, 2013.

[8] Songong Xiao, "A Compact and Dual-band Microstrip MIMO Antenna for LTE Mobile Terminals", ICCC Symposium on Wireless Communications Systems, PP. 474-478. Beijing, China, 2014.

[9] G. Wibisono and T. Firmansyah., "*Design of dielectric resonators oscillator for mobile WiMAX at 2,3 GHz with additional coupling λ/4,"* TENCON 2011 - 2011 IEEE Region 10 Conference, Bali, 2011, pp. 489-493.

[10] Wibisono, Gunawan et al., *"Multiband Bandpass Filter (BPF) based on Folded Dual Crossed Open Stubs".* International Journal of Technology, v. 5, n. 1, p. 32-39, jan. 2014. ISSN 2087-2100.

[11] G. Wibisono, T. Firmansyah, T. Syafraditya., *"Design of Triple-Band Bandpass Filter Using Cascade Tri-Section Stepped Impedance Resonators".* J. ICT Res. Appl., Vol. 10, No. 1, 2016, 43-56 43

[12] Firmansyah T, Praptodinoyo S, Wiryadinata R, et al. (2017). Dual-wideband band pass filter using folded cross-stub stepped impedance resonator. *Microw Opt Technol Lett*. 59(29), 29–2934. doi: 10.1002/mop.30848

[13] Firmansyah, T., Praptodiyono, S., Pramudyo, A.S. C. Chairunissa, M. Alaydrus. (2017). Hepta-band bandpass filter based on folded cross-loaded stepped impedance resonator. Electronics Letters, 53 (16), 1119–1121. doi: 10.1049/el.2017.1121

[14] Teguh F., Supriyanto S., Herudin H., Gunawan W., Mudrik. "Multiband RF low noise amplifier (LNA) base on multi section impedance transformer for multi frequency application". *International Journal of Applied Engineering Research.* Vol. 11., No. 5. Pp.3478-3483. 2016.

[15] Waterhouse, Rod, "Printed Antennas for Wireless Communications", Sussex, England: John Wiley and Sons Ltd, 2007.pp. 183-184, 258