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RECONFIGURABLE BEAMFORMING NETWORK BY USING PASSIVE PHASE SHIFTER

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FAKULTI KEJURUTERAAN ELEKTRONIK DAN KEJURUTERAAN KOMPUTER
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"I hereby declare that this report is the result of my own work except for quotes as cited in the references."

Signature : …….

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RECONFIGURABLE BEAMFORMING NETWORK BY USING PASSIVE PHASE SHIFTER

(*Keywords:Beamforming, Phase Shifter, Butler Matrix, CST)*

This research presented the design of reconfigurable beamforming using phase shifter at input port which operated at Industrial, Scientific and Medical (ISM) frequency (2.4 GHz). Recently, the growing technology of communication systems is rapidly increasing the use of mobile and computer. This will be increasing the demand of data and capacity system. The smart antenna used to rejecting the interference signal, improve the signal to noise ratio (SNR) and increasing the channel capacity of the system. The beam forming network (BFN) is a network that controls the phases and amplitudes of the excitation current for smart antennas. The switched beam system produces the fixed multiple narrow beams and select from them the suitable beam that gives the strongest signal level. The problem is to ensure the mobile in the dynamic range, the system will shift beam one by one until meet the mobile. In this project, phase shifter used to reconfigurable phase of Beamforming network. Result simulation is obtained by using computer simulation technology (CST) in term of S-parameter in magnitude and phase and phase differences between ports. The 4×4 Butler Matrix, was fabricated on Flame Retardant Board type 4 (FR4 board). The beam position was calculated by using result progressive phase shift. Lastly, the simulation and measurement result was compared. The new beam positions are 1R, 2R, 2L, 1L if compare to conventional beam positions are 2R, 1R, 1L, 2L. As a conclusion, the project successful obtained the new beam position of 4×4 Butler Matrix.

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LIST OF ABBREVIATIONS/ SYMBOLS

AF	-	Array Factor
AP	-	Access Point
BER	-	Bit Error Rate
EM	-	Ectromagnetic
FR4	-	Flame Retardant Type 4
GHz	-	Giga Hertz
HPBW	-	Half-Power Beamwidth
IEEE	-	Institution of Electrical and Electronic Engineer
IF	-	Intermediate Frequency
ISM	-	Industrial, Scientific, Medical
LAN	-	Local Area Network
PCB	-	Printed Circuit Board
RF	-	Radio Frequency
SDMA	-	Spatial Division Multiple Access
SINR	-	Signal to Interference and Noise Ratio
SIR	-	Signal to Interference Ratio
SOI	-	Signal Of Interest
SNR	-	Signal to Noise Ratio
TEM	-	Transverse-Electromagnetic
UV	-	Ultra Violet
WLAN	-	Wireless Local Area Network
dB	-	decibel
1R	-	First beam on the right side of polar plot
1L	-	First beam on the left side of polar plot
2R	-	Second beam on the right side of polar plot
2L	-	Second beam on the left side of polar plot
W	-	Width of rectangular Microstrip line
L	-	Length of rectangular Microstrip line
εr	-	Dielectric constant
h	-	Substrate height

λg	-	Guided wavelength
N	-	Number of elements
d	-	distance between antenna elements
θ	-	phase
β	-	phase difference between port elements
k	-	wave number
$\lambda 0$	-	wavelength in free space
l	-	transmission line length
Zo	-	characteristic impedance
W	-	transmission line width
εeff	-	effective dielectric constant
c	-	velocity of light in free space
fr	-	operating frequency

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CHAPTER I

INTRODUCTION

1.1 Background of the Project

Recently, the growing technology of communication system is rapidly increased the user of mobile and computer. This will be increase the demand of data and capacity system. To overcome this problem, several studies about the smart antenna have done. The smart antenna used to rejecting the interference signal, improve the signal to noise ratio (SNR) and increasing the channel capacity of the system. Smart antenna will be dividing in two main categories, first, adaptive antenna array and switched beam system. An adaptive antenna array aims to reject automatically interference signals by modifying its radiation pattern using adaptive algorithms. This modification will steering the main lobe in desired signal direction and create the null pattern in interference directions. This will increase the signal to noise ratio.

However, the design of adaptive antenna array is more complex than the switched beam system. Switched beam system produce the fixed multiple narrow beams and select from them the suitable beam that gives the strongest signal level. To ensure the user in the dynamic range, the system will shift beam one by one until meet the user. The first class is based on using discrete beams and switched them in

order to track desired with best beam. The second class based on pattern modification that to create same view, by design a new class of micro strip butler matrix, which can be used as feeding network antenna for multiple array antenna.

The butler matrix is easily producing the various beams signal with different directions. But different for adaptive antenna array, that use more intelligent process to detect the desired mobile user and reject the interference mobile. Until now, most studies had done on the simulation process to observe the performance of beam forming network by using butler matrix [1].

1.2 Problem Statement

Recently, the growing technology of communication system is rapidly increased the user of mobile and computer. This will be increase the demand of data and capacity system. The smart antenna used to rejecting the interference signal, improve the signal to noise ratio (SNR) and increasing the channel capacity of the system. The beam forming network (BFN) is a network that controls the phases and amplitudes of the excitation current for smart antennas. Switched beam system produce the fixed multiple narrow beams and select from them the suitable beam that gives the strongest signal level. The problem is to ensure the mobile in the dynamic range, the system will shift beam one by one until meet the mobile. In this project, phase shifter used to reconfigurable phase of Beamforming network

1.3 Objective

The main objective of this research is design, simulate and fabricate a reconfigurable beam forming using phase shifter at input port with operating frequency 2.4 GHz. In this research, the microstrip line has been used as a phase shifter and act as reconfigurable phase difference. The other objective is to minimize the Butler Matrix. The parameter of beamforming such as S-parameter, phase shift, phase different, ß and beam position will be measured.

1.4 Project Scope

The main scope in this research is to design reconfigurable beam forming network by using phase shifter. For design reconfigurable beam forming, the 4×4 butler matrix is commonly chosen, that because butler matrix able to generate multi-beam of input signal for antenna with different angle direction. The all component of4×4 butler matrix and phase shifter will be design separately and was simulated in CST suite software. The all component were analyze with consider their characteristic with refer to S-parameter result. After finish simulation and analyze part, the design will fabricate on FR4 board and the chemical etching will be used to complete the fabricate part.

1.5 Project Methodology

To make this research is done at in time; the flow chart is needed to handle this research follow the right steps. The figure 1.1 has shown the flow chart for this research. At first step for beginning this project, literature review activities need to gather information about beam forming and study the design of previous research of beam forming network system. This important to up the basic fundamental about the theories, parameter, design and different method to design beam forming network. The literature study also review about the component in the beam forming network design. The butler matrix and the other method also are review and understand the fundamental of them.

After understand of the fundamental butler matrix, the components in the butler matrix are constructed. In the 4×4 Butler Matrix, four branch line coupler, two crossover coupler and two phase shifter were construct separately by using CST Suite 2009 software. The simulation for early design of branch line coupler was analyzed and the S- parameter was observed and recorded. The good branch line coupler produce 90° phase shift between through port and coupled port when some power incoming the input port, then equally divided at through port and coupled port. While no power out at isolated port. The 4×4 Butler Matrix was simulated and the result of S-parameter was recorded.

Then the phase shifter is designed and will integrate at input port of Butler Matrix. After that, the combination was simulated and the data of parameter are recorded. The fabrication process will be proceeding with printing the design on the transparency and data will be transfer to the FR4 board using UV machine. Then the FR4 will be etching with chemical liquid. For the last stage, the board will solder with connector at input and output port. The design will be measured by using Spectrum Analyzer. All data will be recorded and comparison with the conventional design will be made. The report writing comes out with the measurement and simulation result.

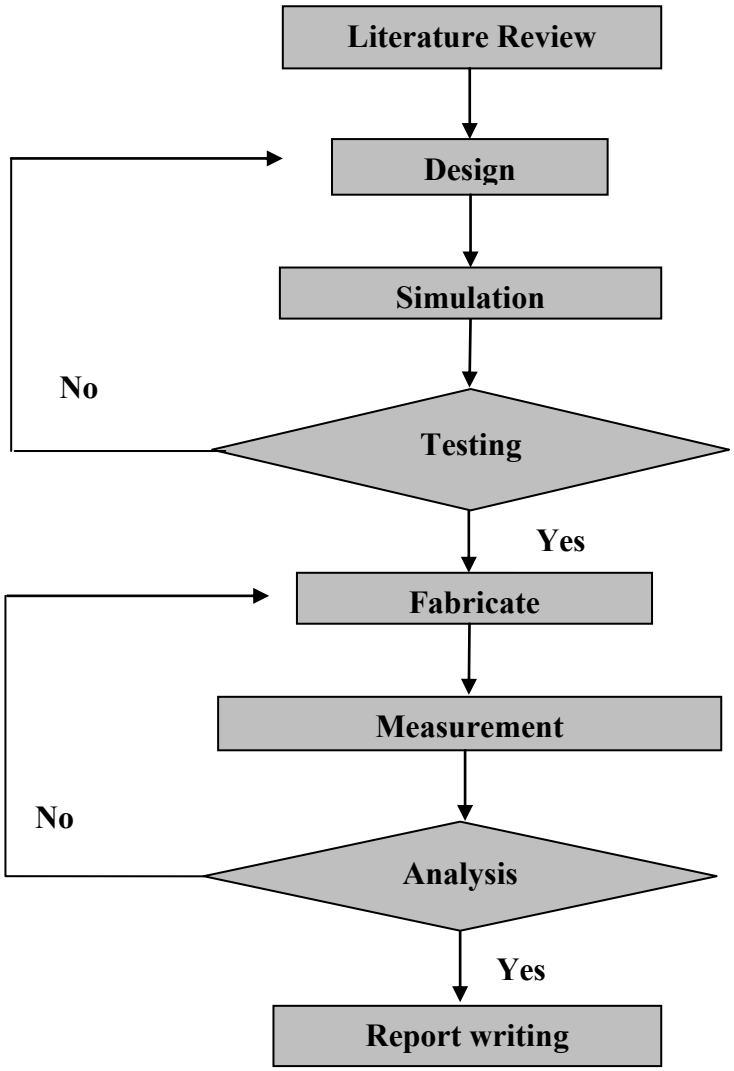

Figure 1.1: flow chart of methodology

1.6 Report Outline

This report is organized in fives chapters. Chapter one provides a general idea of the project and the introduction of the project. Chapter two describes theory and characteristic of butler matrix. Chapter three explains the methodology including the calculating and simulation process. Chapter four discusses about the result and analysis project. Lastly, chapter five includes the conclusions and future work to improve this project.

1.7 Summary

In this chapter, the project background, the objective, scope of project and research methodology is stated briefly, so that the reader can understanding clearly about this project.

CHAPTER II

LITERATURE REVIEW

2.1 Smart Antenna

Smart antenna is design with purpose to reduce the co-channel interference fading in mobile system with rejecting the interference signal and increasing the desired signal beam. Those happen because the number of mobile user increasing rapidly. Then, by using the smart antenna technology, the wireless system would be better coverage and capable to increase the signal to noise ratio (SNR) of the system [1].

The basic work for smart antenna can describe by using human body system. As example of human body system, two people had conversation in the room with first people closed eyes (refer figure 2.1). Conversation remain with second person speak to the first person as a listener. The listener detects the direction of voice and the time delay between the voices comes out from speaker. The brain act like human signal processor, where process the voice detect by two ears at different of arrival (DOA) of signal by refer the signal of interest (SOI). After know the direction of signal, the brain will boost up the strength of signal by focus at the voice direction.

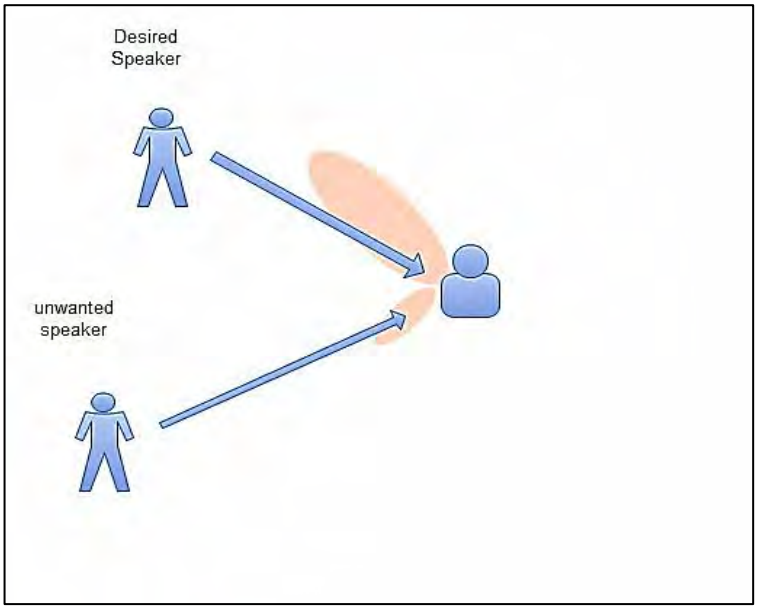

Figure 2.1: analogy of human body system

If have additional speaker interference in the conversation, the listener will tuning the voices at different frequency of voice and classification the second speaker as interference signal and concentrate at first speaker voice as signal. The listener also can give feedback in the conversation with transmit the feedback voice using mouth toward the speaker. The signal processor will measured the signal direction of arrival (DOA) of the signal of interest (SOI) and reproduce the excitation (gain and phase of the signal) to generate the radiation pattern with tuning out the interference signal [4].

Basically, the smart antenna system refers to cell sectoring concept, where the coverage is consists of multiple beams. In the cell sectoring concept, the single Omni directional antenna is replaced with several directional antennas for overcome the overload in the wireless services. The cell sectoring divided in three section of 120 degree as like in figure 2.2. But in the cell sectoring concept, the capacity problem is not fully resolve, and then the smart antenna system used to solve this problem. The smart antenna provide the better coverage because the system can focus on the wanted signal and produce radiation pattern, while reject the interference signal. Besides that, the smart antennas have lower bit error rate, which mean improvement of capacity of system.

Gain = 10 log (M) [1]

M = number of beams per sectors

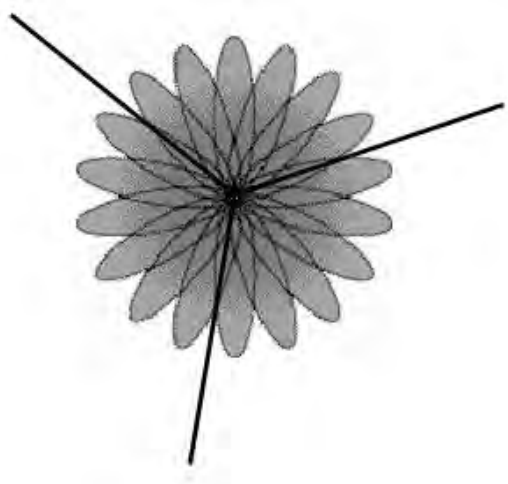

Figure 2.2: coverage 120° [4]

Smart antenna system has two main category; switched beam systems and adaptive antenna array. The switched beam systems are generated multiple narrow beams and selects from them the suitable beam that give the strongest signal level. By selecting one or more signal beam, the power transmit in through port direction can be maximized. The switched beam systems purpose to improve the gain according the location of user, and also used to locate the user of mobile with using the reconfigurable beam forming network. The beam will switch until the user was detected as in figure 2.3(a).

Another one of smart antenna category is adaptive antenna array. The aims of adaptive antenna array is to reject the interference signal automatically by make modify at its radiation pattern by using adaptive algorithms [2]. By customize the patterns, the system will allow steer the main lobe in signal direction and then creating pattern null in interference user. The adaptive antenna array operation is more intelligent from the switched beam antenna. The Figure 2.3 has shown the comparison between them.

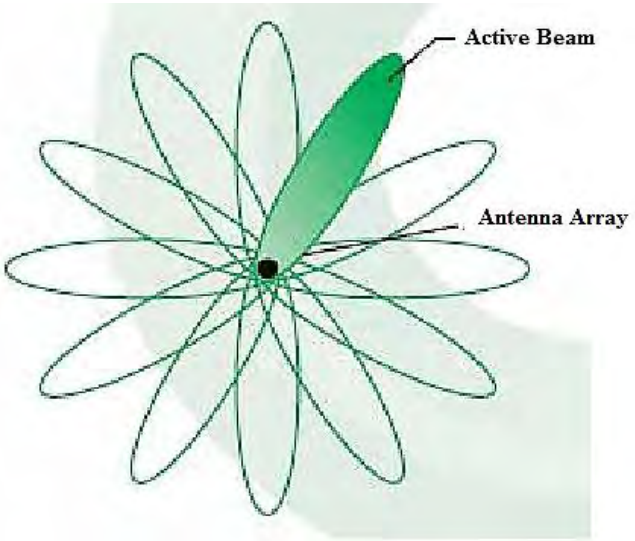

Figure 2.3 (a)

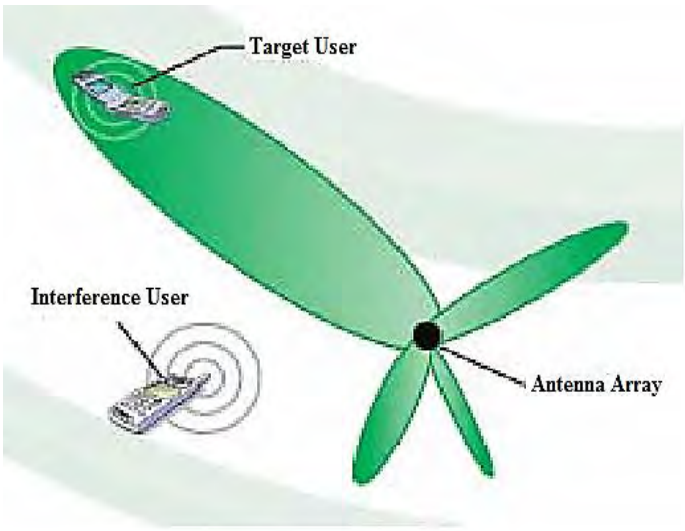

Figure 2.3 (b)

Figure 2.3: Radiation pattern a) Switched beam antenna, b) Adaptive antenna array [2]

In comparison the switched beam system have low cost and simple implementation and less complexity than adaptive antenna array that have more complexity circuit design and expensive cost needed. The switched beam system constructed with antenna array, a beam forming network, RF switch and simple