# WIDEBAND COUPLER FOR BUTLER MATRIX ANTENNA BEAMFORMING

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"***The difference between a successful person and others is not a lack of strength, not a lack of knowledge, but rather a lack of will."***

Specially dedicated to my beloved Family ***Dad, Mom,GrandMother Inthar, Shahad,Massara***

To my beloved uncles ***uncle Thiar, uncleAli and their lovely families***

To my best brothers in Life ***Abduallah, Khalid, Abo Jasem***.

To The Greatest one in Our Hearts For Ever, ***Grandfather Sabri***

To Your Soul ***Uncle RAID***

To ***My Angel***

**I Love you All**

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## ABSTRACT

This work focuses on the design of a Wideband Branch Line Coupler (BLC) by using open circuits coupled lines technique. The design is implemented by adding four open circuits coupled lines to the structre of the conventional Branch Line Coupler. The coupler operates at 3.8 GHz with a wideband bandwidth of 1.66 GHz, in which the fractional bandwidth is 43.69%. Then the proposed design was implemented using CST microwave tool and the simulation results of the S-parameters obtained from CST microwave simulated achieving a coupling factor of -3dB and 90° phase diffrence between the two output port at the frequency of 3.8 GHz , the fabrication process and the experiment results of the proposed prototype wideband BLC was discussed and compared. The simulated results, and the measured results similar with wider bandwidth of 1.62 GHz and fractional bandwidth of 42.63% with reducation size of 28.2%.

# ABSTRAK

Kerja ini memberi tumpuan kepada reka bentuk yang Wideband Cawangan Line Coupler ( BLC ) dengan menggunakan litar terbuka ditambah teknik garisan. Reka bentuk ini dilaksanakan dengan menambah empat litar terbuka ditambah kepada barisan structre daripada konvensional Cawangan Line Coupler. Pengganding beroperasi pada 3.8 GHz dengan lebar jalur jalur lebar daripada 1.66 GHz , di mana lebar jalur pecahan adalah 43,69 %. Kemudian reka bentuk yang dicadangkan dilaksanakan menggunakan CST alat gelombang mikro dan keputusan simulasi S- parameter yang diperolehi daripada CST gelombang mikro simulasi mencapai faktor gandingan -3dB dan $90^{\circ}$ fasa diffrence antara dua pelabuhan output pada frekuensi 3.8 GHz , proses fabrikasi dan keputusan eksperimen prototaip yang dicadangkan Wideband BLC telah dibincangkan dan dibandingkan. Keputusan simulasi , dan keputusan diukur sama dengan lebar jalur yang lebih luas daripada 1.62 GHz dan lebar jalur pecahan 42,63 % dengan saiz reducation daripada 28.2 %.

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# LIST OF ABBREVIATION

| | | |
|---|---|---|
| BLC | - | Branch Line Coupler |
| QoS | - | Quality Of Service |
| GSM | - | Global System for Mobile |
| CDMA | - | Code Division Multiple Access |
| CST | - | Computer Simulation Technology |
| UWB | - | Ultra-wideband |
| Ω | - | Ohm |
| dB | - | decibel |
| FR4 | - | Fire Retardant Type 4 |
| BW | - | Bandwidth |
| PCB | - | Printed Circuit Boards |
| Hz | - | Hertz |
| GHz | - | Giga Hertz |
| mm | - | Millimetre |
| RF | - | Radio Frequency |
| EM | - | Electromagnetic |
| UV | - | Ultraviolet |

# LIST OF SYMBOLS

| | | |
|---|---|---|
| *h* | - | Dielectric substrate thickness |
| *L* | - | Length |
| *W* | - | Width |
| *Γ* | - | Reflection coefficient |
| *Z0* | - | characteristic impedance |
| $Z_L$ | - | load impedance |
| λr | - | free-space wavelength |
| εr | - | dielectric constant of the substrate |
| *t* | - | Patch thickness |
| *c* | - | Speed of light 3x 10-8 m/s |
| *G* | - | Conductance |
| *Л* | - | *Pi* |
| η | - | Efficiency |
| W1 | - | width of feed line |

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# CHAPTER 1

# INTRODUCTION

## 1.1 Introduction

Nowadays, many wireless communications systems are operated with multiple standards such as IEEE 802.11b/g for 2.4 GHz and IEEE 802.11a for 5 GHz, where the need for developing these systems to provide multiband microwave circuit that can be operated at two or more than arbitrary frequencies bands. Also the vast growth of wireless communications systems is creating a huge opportunity for the researcher community to search for new technologies which would be implemented into current wireless communications infrastructure to provide a wideband frequency for each user. Furthermore these new technologies bring better quality and new services for the operators companies.

Another issue when talking about higher speed performance and higher user capacity in wireless communications systems is the interferences, Co-Channel and Multipath interferences where these two factors contribute and degrade the quality of wireless communication systems and therefore degrades the quality of the service (QoS). One way to reduce these interferences is use beamforming network in an antenna array.

Beamforming in an antenna array is presented as a new technology for higher user capacity in 3G wireless network by effectively reducing multipath and Co-channel interferences. [1] Also this way usually refers as smart antenna [2], where smart antenna is a new technology and has been applied to the mobile communication systems such as GSM and CDMA. [3]

Beamforming is a signal processing technique used in sensor arrays for directional signal transmission or reception. [2] Its a technique of how to transmit the signal in specific direction, and that would defiantly reduce the Co-channel and fading interferences.

One way to transmit the signal in specific direction to form a beam is by using Butler Matrix in an antenna array network. Where to provide a multiband frequency one important component in Butler Matrix called coupler must be used. Coupler in Butler Matrix defines as a power divider, combiner microwave device with phase shift of 90 degree, and this type of coupler named Branch Line Coupler (BLC). BLC usually has four ports network and resonant at single frequency and narrow bandwidth.

## 1.2 Problem Statement

Butler matrix is a feeding network to an array antenna that allows the beam to be directed in desired direction. A wideband Butler matrix would allow the same antenna system to be tuned to operate at different frequencies, thus reducing the cost of having different circuit at different frequencies. BLC is the main component of Butler matrix, which is conventionally designed at certain frequency and possesses a very narrow band. Therefore, this work focus on designing a wideband BLC in order to have a wideband Butler matrix to feed the array antenna system and allow the beam to be formed in different direction.

## 1.3 Research Objectives

1. To design, simulate, and fabricate a wideband and compact Branch Line Coupler that can be used in Butler Matrix for antenna beamforming.

2. To analyze the performance of the designed Branch Line Coupler.

## 1.4 Scope Of Work

The scope of the works of this project would be summarized to first do the theoretical analysis and parameters calculation of BLC coupler. Then the proposed design would be implemented using CST Microwave tool to simulate the proposed BLC coupler proposed design. The Simulation results analysis of the proposed BLC design will be presented and the Optimization and Fabrication of the Proposed BLC design on FR-4 Board will be introduced also. Finally the simulated and measured results are analysed and compared.

## 1.5 Project Organization

The Following is the introductory chapter, the rest of the thesis organized as follow:

Chapter 2 introduce the recent works and reaches for the wideband branch line coupler. An overview of the main and recent technologies used in designing the wideband branch line coupler will be presented. In addition an extensive literature review for wideband branch line coupler and theory beyond its implantation.

Chapter 3 introduce the project methodology, the design steps and the calculations of certain parametras, the simulation tools and the process of the design will be discuss, while the fabrication process will be introduced further in this chapter.

Chapter 4 introduce the steps of the design the wideband branch line coupler comparied with the convetional branch line coupler, the simulation results for both design will be presented in this chapter.

Chapter 5 introduce the fabrication process and the prototype of the wideband branch line coupler and the conventional branch line coupler, the measeurments results for both designs will be provided and comparied with the simulated results.

Chapter 6 provides a summary of the main contributions and findings of the project study and concludes the accomplished work, its also introduce suggestions for future works related to this project.

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