COMPACT PLANAR HYBRID RING COUPLER WITH EMBEDDED MEANDER LINE

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COMPACT PLANAR HYBRID RING COUPLER WITH EMBEDDED MEANDER LINE

by

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SYMBOLS

c	Width of copper ring
ε_r	Dielectric constant
ε_o	Permitivity constant, $8.85 \times 10^{-12} Fm^{-2}$
ε_{eff}	Electrical length
f_o	Central frequency
GHz	Giga Hertz
H	Thickness of substrate
λ	Wavelength
T	Reflection coefficient
t	Thickness of copper
ω	Resonant frequency
Z_o	Characteristic impedance
Z_{in}	Input impedance
S_{11}	Return loss at Port 1
S_{22}	Return loss at Port 2
S_{12}	Isolation loss from port 1 to port 2

S_{21} Isolation loss from port 2 to port 1

ABBREVIATIONS

CST Computer Simulation Technology

dB Decibel

IEEE Institute of Electrical and Electronic Engineer

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ABSTRAK

Penyambung hibrid boleh digunakan untuk menanggalkan dan meningkatkan pengasingan antara pelabuhan antena. Ia biasanya digunakan dalam aplikasi seperti rangkaian suapan antena, pembahagi kuasa, penggabungan, pengadun dan peralihan fasa digital. Dalam projek ini, ia memberi tumpuan kepada bagaimana untuk merancang coupler cincin hibrid planar padat dengan garis meander tertanam dengan menggunakan CST. Cadangan coupler cincin hibrid adalah kerana ia lebih baik dari segi kos pengeluaran yang rendah daripada teknik lain, kehilangan pulangan yang baik dan persembahan pengasingan dan mengurangkan kos. Oleh itu, ia boleh menjadikan peranti itu berfungsi dengan prestasi yang lebih baik. Dalam karya ini, ia tertumpu pada bagaimana untuk mengurangkan saiz coupler cincin hibrid supaya ia dapat memperoleh bacaan Parameter-S yang baik. Reka bentuk yang dicadangkan direka dengan menggunakan papan litar bercetak Rogers RO4003C dengan pemalar dielektrik ε_r, 3.55 mm, ketebalan substrat, H, 0.81 mm dan ketebalan tembaga, t, 0.035 mm. Reka bentuk yang dicadangkan boleh dikendalikan pada 2.4 GHz. Hasil simulasi dianalisis dan dibandingkan secara teoritis dan praktikal supaya ia mencapai keperluan Parameter-S.

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ABSTRACT

Hybrid coupler can be used to decouple and increase the isolation between antenna ports. It is normally used in applications such as antenna feed networks, power dividers, combiners, mixers and digital phase shifters. In this project, it is focuses on how to design compact planar hybrid ring coupler with embedded meander line by using CST. The proposed of hybrid ring coupler is because it have better in terms of low production cost than other techniques, good return loss and isolation performances and reduce the cost. Thus, it can makes the device to perform with better performance. In this work, it is mainly focused on how to reduce the size of hybrid ring coupler so that it will obtain good S-Parameters readings. The proposed design is fabricated using Rogers RO4003C printed circuit board with dielectric constant of ε_r, 3.55 mm, thickness of substrate, *H*, 0.81 mm and thickness of copper, *t*, 0.035 mm. The proposed design can be operated at 2.4 GHz. The simulation result were analyzed and compared theoretically and practically so that it achieve the requirement of S-Parameter.

CHAPTER 1

INTRODUCTION

1.1 Research Background

In recent years, the applications of radio frequency (RF) and microwave engineering are widely used in wireless communication systems, wireless security systems, radar and navigation systems, and broadcasting as well as bio-medical applications. One of the most commonly used passive devices is the hybrid coupler. Couplers can be found in many applications, including dividers and combiners, modulators and demodulators, balanced mixers, power amplifiers, Butler matrices, and in the feed network of antenna arrays, among others. 180º hybrid couplers and 90º hybrid couplers have many similar characteristics. For example, they are typically employed as equally split 3 dB power dividers, and they both possess a coupled port.

Hybrid coupler is a four-port device, where a wave entering any port excites two other ports with prescribed amplitudes, whereas the remaining port is isolated [1]. The coupler uses two transmission lines set close enough together such that energy passing through one is coupled to other. There are two types of hybrid coupler that is widely used in RF and microwave engineering, Branch-line coupler and ring coupler. Upon comparison of these couplers, the rat race ring coupler was chosen for this project due to its better in terms of low production cost than other techniques and good return loss and isolation performances. The rat race ring coupler is designed to minimize the coupling between the co-located antenna ports of a dual polarized antenna which is the intended application for this research project.

1.2 Problem Statement

In this new wireless communication system, dual polarized antenna is widely used in MIMO communication as it can be co-located. Dual polarized antennas are usually more compact compared to conventional antennas and can be designed such that it can fit into small devices such as mobile phones and wearables. Thus reducing the size as well as the cost of the microwave system. However, when designing a compact dual polarized antenna, one of the major problem is achieving perfect isolation between the antenna ports so as to not interfere with each other. For example, in [2], at resonant frequency, the return loss is quite good but the isolation loss between antenna port 1 and port 2 is around -8 dB which is quite high.

One method to improve the isolation between the antenna ports in a dual polarized antenna is by employing a hybrid coupler. A hybrid ring coupler can decouple, degrade the return loss and increase the isolation between antenna ports. Either 180º hybrid couplers (branchline coupler) or 90º hybrid couplers (rat-race ring coupler) can be utilized. Since a dual polarized antenna is usually a compact design, a hybrid coupler can also be designed to be more compact. A compact hybrid coupler can then be printed onto a microstrip to achieve a planar structure. The hybrid ring coupler can be compacted using the meander line method, by utilizing the vacant space inside the conventional rat-race coupler. The meander method is where the microstrips of the ring coupler are bended to inside, so as to reduce the occupied area. The meander line has been widely used for application to compact transmission line due to its small layout area, which enabled a reduction of device size. Therefore, this research aims to design and evaluate a compact meander line hybrid ring coupler at operating frequency of 2.4 GHz to improve the isolation between antenna ports in a compact co-located dual polarized antenna. The size of the new structure is 66.67% less than the conventional ring hybrid coupler at the same center frequency.

1.3 Objectives

In this research, three objectives are set to be achieved:

i. To design and optimize four ports Compact Hybrid Ring Coupler with Embedded Meander Line at frequency 2.4GHz

ii. To fabricate and build the prototype of the Compact Planar Hybrid Ring Coupler With Embedded Meander Line

iii. To test and evaluate the proposed prototype's performance

1.4 Scope of project

The scope of this project is to design, simulate, optimize, fabricate and analyze a compact planar hybrid coupler. The design of this compact coupler is simulated using CST software at the operational frequency of 2.4GHz which is in the S-Band frequency range. The hybrid ring coupler design is fabricated using RO 4003C with following parameters:

i.	Thickness of substrate, H:	0.81 mm
ii.	Relative permittivity of substrate, ε_r:	3.55 mm
iii.	Thickness of copper, t:	0.035 mm

1.5 Thesis Outline

The report has been divided into five main chapters. The topics covered mainly stress on design and fabrication of proposed Hybrid ring coupler.

Chapter 2 is dedicated to illustrating the relevant literature and the new employment related to the subject performed by other research worker. The content includes the theoretical background of the projection which consists of the basic apprehension of ring coupler, the study of hybrid ring coupler, a basic understanding of meander line and wideband/broadband ring coupler.

Chapter 3 focuses on methodologies adopted for the study. It consists of explanation for the constituent parameters of hybrid ring coupler. The project flow chart is included to show pictorially the determination and procession of each task involved during performs the project. Furthermore, the chapter includes the design of ring coupler which is four port hybrid ring coupler by using CST software including the layout designs.

Chapter 4 presents the simulation results obtained from CST software and measured from visual network analyzer (VNA). Results obtained are measured by referring on magnitudes of S-parameters and reflection coefficient. The obtained results also are then discussed and analyzed thoroughly.

Lastly, Chapter 5 show the conclusion of the study of the project. Some recommendations are proposed for future works in order to improvise the performance of the proposed design.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Hybrid couplers are indispensable components in various microwave integrated circuit (MIC) applications such as antenna feed networks, power dividers, combiners, mixers and digital phase shifters [2]. This hybrid coupler commonly used are 180^o hybrid-ring and 90^o branch-line couplers with improved bandwidth have also been reported. [3]

2.1.1 Hybrid Ring Coupler/ Rat-Race Coupler

The hybrid ring coupler has been widely used in microwave power dividers and combiners. The hybrid ring coupler have four-port network with equal power-split between the two output ports, each of the port are placed one quarter wavelength away from each other around the top half of the ring. However, three quarter wavelengths is the bottom half of the in length. The ring has its characteristic impedance of factor squred root of 2 compared to port impedance. A signal input on port 1, will be split between two ports which is port 2 and port 3, while port 4 will be isolated. Figure 2.1 shows the physical configuration of the hybrid ring coupler. An even-odd-mode method is used to analyze the hybrid ring coupler. When a unit amplitude wave is incident at port 4 hybrid ring coupler, this wave is divided into two components at the ring junction. The two component waves arrive in phase at ports 2 and 3, and 180^o out of phase at port 1. By using an even-odd-mode analysis technique, this case can be decomposed into superposition of two simpler circuit. [3] However, the advantage of this coupler is it have better in terms of low production cost than other techniques, good return loss and isolation performances and reduce the cost.

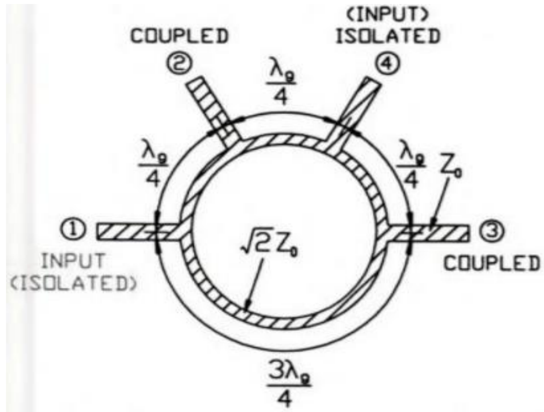


Figure 2.1 : Physical layout of hybrid ring coupler [3]

2.1.2 Branch-line Couplers

Basically branch-line couplers are 3dB, which is four ports directional couplers having a 90° phase difference between two output ports named through and coupled arms. In another named of Branch-line couplers is Quadrature Hybrid are often made in microstrip or stripline form. However, Branch-line coupler has four ports which is a common port, an isolated port, and two coupled ports with a 90-degree phase difference. This couplers are widely used in various SHF devices such as power splitters, power combiners, phase shifters and many more. A branch-line coupler is a four-port network that can be used either as a power divider or as a signal combiner [4]. This coupler are able to provide a plus or minus 90-degree phase shift and also can split the signal into two pieces. However, it has four quarter-wavelength transmission lines. In order to analyze this circuit use even and odd mode analysis [5]. The mode comes in from the left ports that are in-phase, while an even have a virtual open. Likewise for the Odd Mode, where we have an in-phase signal on one port, and an out-of-phase signal on the other port, can use symmetry, and can make this into a virtual ground because it can split up any impedance between this into two pieces and call this ground because it's not going to move because the two signals are symmetric. The advantage of this coupler is easy construction but the disadvantage of this couplers is its narrow operational bandwidth because perfect match is only obtained at design frequency where each line is exactly **λ**/4 long. At other frequencies, each line length is no longer **λ**/4 and signal attenuation increases while signal isolation decreases between the relevant ports [6].

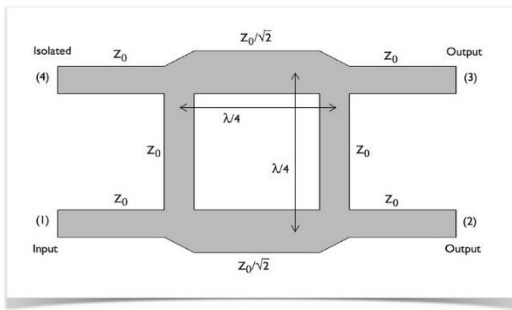


Figure 2.2: Branch-line coupler [5]

2.1.3 Comparison between coupler

There is two type of coupler which is widely used among researchers. Table 1 is a summarization of all advantages and drawbacks between all the coupler [7].

Table 2.1: Advantages and drawbacks of Coupler

Coupler	Advantage(s)	Drawback(s)
Ring / Rat race coupler	• Better in terms of low production cost than other techniques [8] • Good return loss and isolation performances [9] • Reduce the cost [10]	• Lower microwave frequencies and higher-order harmonics [9]
Branch-line / Quadrature coupler	• Miniaturize the circuit significantly and enhance the bandwidth [11]	• very large and not suitable to fabricate by PCB planner microstrips technology [12] • low frequencies it will consume a significant amount of circuit area and provides a narrow fractional bandwidth of 10 to 20% [11]

Therefore, Ring Coupler highlights all the ideal parameters characteristic such as wide operation bandwidth, acceptable return loss, good port-to-port isolation and excellent amplitude and phase imbalance. Thus, it is the best choice to use for the proposed design in this work.

2.1.4 Meander Line

Meander line antenna is one type of the microstrip antennas. Meander line technology allows designing antennas with a small size and provides wideband performance. It is a slow-wave circuit which consists of a number of parallel tapes uniformly spaced and connected in series [13]. Meander line antennas are an interesting class of resonant antennas and they have been widely studied in order to reduce the size of the radiating elements in wire antennas: monopole, dipole and folded dipole type antennas. In meander line antennas, the wire is continuously folded to reduce the resonant length. Increasing the total wire length in antenna of fixed axial length lowers its resonant frequency. According to S. Best, when made to be resonant at the same frequency, the performance characteristics of these antennas are independently of the differences in their geometry or total wire length. Uniform U- MLA structures, the geometry are described to 3 parameters: the number of turns, and length of the horizontal and vertical section. For NUMLA these are no tied values for the variables. Compact frequency tunable planar meander line monopole antennas for mobile terminal applications are present [14]. The layout of a typical meander line is shown in Figure 2.3. To extract the equivalent inductance of a meander line, the total inductance is found from the sum of the self-inductances of all the segments and the mutual inductances between all combinations of the straight segments [15]. Figure 2.4 shows the example of the meander line. Therefore, in order to compact the ring coupler design, the meander line method is utilized to shorten the distance between the ports of the coupler by maximizing the space surrounding it.

Figure 2.3: Characteristic geometrical dimensions of the meander inductor

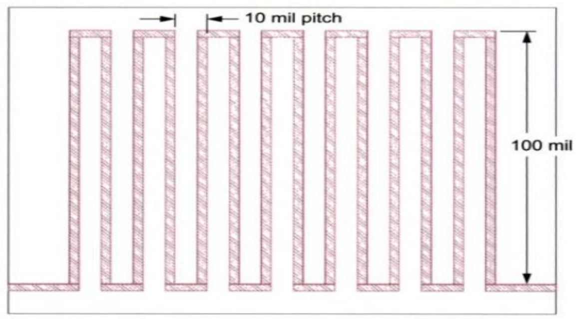


Figure 2.4: Meander Line [16]

2.1.5 Hybrid Coupler with Meander Line

In order to miniaturize the hybrid coupler, the spaces S were minimized to where the coupling between them cannot be ignored. In usual design rule of microstriplines, the space between lines should be at least three times of line width unless coupling between them is necessary. The dimensions of the conductor width W, the conductor gap G and the meander line space S were optimized to miniaturize the hybrid without appreciable degradation in electrical performance [8]. Figure 2.5 shows the cross sectional view of the 90 degree hybrid coupler. The proposed structures require high accuracy in the manufacturing facilities and they are built with a 100Ω reference impedance, which is necessary to decrease the rat-race line width in order to achieve the required space-filling details [10].

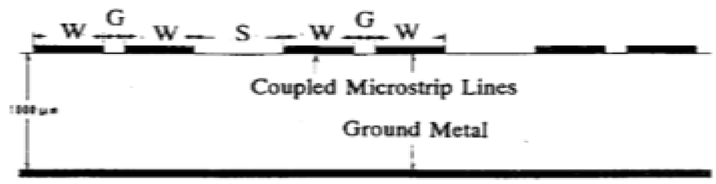
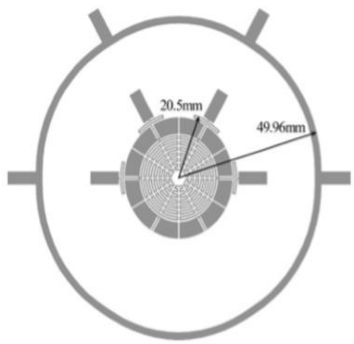
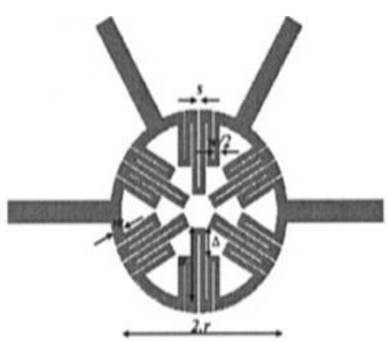


Figure 2.5: shows the cross sectional view of the 90 degree hybrid coupler

Table 2.2: The previous research design and the size reduction

Design	Size reduction
Compact rat-race ring coupler with meander line high-impedance transmission line and port impedance matching [17] 	Around 60%
Compact rat-race hybrid coupler using meander spacefilling curves [10] 	between 15% and 30%

2.2 Performance Matrix of Hybrid Coupler

Various related theoretical backgrounds will be discussed further such as scattering parameters, return loss, insertion loss, matching properties and bandwidth as well as relative frequency response. Along with that, the formulas are also provided.

2.2.1 Scattering Parameters (S-Parameters)

Generally, S-Parameters are related to power traveling waves in order to avoid the concept of voltage and current are complicated to relate to network performance. Before the S-Parameters were introduced, the Y and Z parameters were advent with the mentioned concept.

S-Parameters are exhibit in a matrix format which comes in a row and column spaces as it describes the input and output relationship at the number of ports in the network system. In the electrical system, the S-Parameters represents the element S_{11}, S_{12}, S_{21}, S_{22}. However, S_{11} and S_{22} indicate the reflection coefficients, T while S_{12} and S_{21} indicate the transmission coefficient, T. Reflection coefficient, T is the ratio of the reflected wave and incident wave while transmission coefficient, T is the ratio of transmitted wave and incident wave.

S-Parameters can be represented by S_{ab} which *a* denotes the power wave going into the port while *b* denotes the power wave leaves from the port. For example is two-port network is used, S_{21}, it is means power wave is transmitted from port 1 to port 2.

In addition, each of the parameter involved mentioned above gives its own definition as below:

- S_{11} shows the input reflection coefficient at port 1
- S_{12} shows the reverse transmission coefficient from port 2 to port 1

- S_{21} shows the forward transmission coefficient from port 1 to port 2
- S_{22} shows the output reflection coefficient at port 2

From the above list, some related parameters can be represented by them. Firstly, S_{11} denotes as return loss, T, S_{21} denotes as transmission loss, T and S_{12} is denotes as isolation loss. Both of the return and isolation losses can be calculated from the reflection coefficient with the equation in (2.1) and (2.2) [7].

$$Return\ loss, RL = -20\log|T| \tag{2.1}$$

$$Isolation\ loss, IL = -20\log|T| \tag{2.2}$$

Referring to figure 2.5, it is an illustration of wave procedure used in S-Parameters for a two-port network. Denotes that *a* is the power wave going into the port while *b* is the power wave leaves from the port. Both *a* and *b* are resembled the incident and reflected waves respectively.

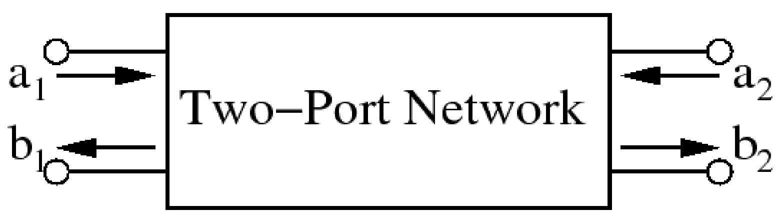


Figure 2.6: Photo of two-port network [18]

S-Parameters are a mathematical construct that determines the RF energy propagate through a multi-port network. S-parameters describe the response of N-port network to signal incident to any or all ports [19]. There are four S-Parameters in two-port network which are S_{11}, S_{21}, S_{12} and S_{22}. Figure 2.6 shows the model of two-port network with the input and output ports.

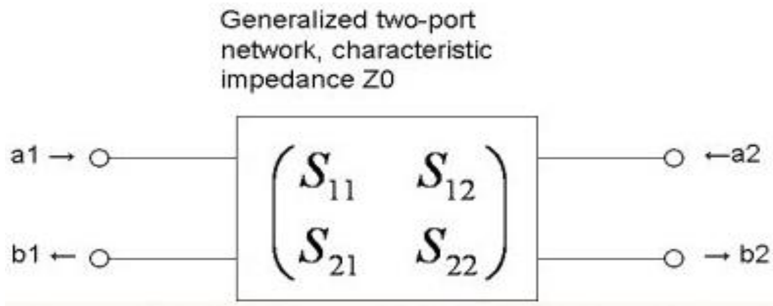


Figure 2.7: Model of two-port network [19]

From figure 2.6, *a* indicates the power going into the port while *b* indicates the power leave from the port. Moreover, S_{11} implies that how much power injected at port 1 and resulting signal from port 1is measured. For S_{21} it means the signal injected at port 1 and resulting signal exist at port 2 is measured. All of the equations below show the equations of two-port network.

$$b_1 = S_{11} * a_1 + S_{21} * a_2 \tag{2.3}$$

$$b_2 = S_{21} * a_1 + S_{22} * a_2 \tag{2.4}$$

$$S_{11} = \frac{b_1}{a_1}\Big| a_2 = 0 \tag{2.5}$$

$$S_{21} = \frac{b_2}{a_1}\Big| a_2 = 0 \tag{2.6}$$

$$S_{12} = \frac{b_1}{a_2}\Big| a_1 = 0 \tag{2.7}$$

$$S_{22} = \frac{b_2}{a_2}\Big| a_1 = 0 \tag{2.8}$$

2.2.2 Return Loss

Return loss is an amount of signal that reflected back towards the signal source by a device due to impedance mismatch. The amount of reflected power is represented by dB. However, the higher the number of gains measured in negative value, the smaller number of power reflected out. From return loss equation, the reflection coefficient can be determined. Thus, VSWR and percentage reflected power can be calculated to determine the match properties of the design. The equation can be obtained as follows [7]:

$$VSWR = \frac{1+|T|}{1-|T|} \tag{2.9}$$

$$Return\ loss = -20\log|T| \tag{2.10}$$

$$T = 10^{\frac{-RL}{20}} \tag{2.11}$$

$$Perentage\ of\ reflected\ power, \% = (100)(|T|^2) \tag{2.12}$$

Return loss can be denoted as S_{11}. It is one of the important parameters to be measured. It means that the difference between transmitted signal power and the power signal reflections caused by matching impedance. An ideal network will have minimum return loss approaching to zero which is return loss should be a higher negative value at its resonance frequency. S_{11} is measured in decibel (dB) as in Eq.

$$Return\ loss = S_{11} = 20\log|S_{11}| \text{ in dB} \tag{2.13}$$

2.2.3 Insertion Loss

Insertion loss is a loss in power that attenuates the device in dB. It designate the input power to be declined at the output port equally. Hence the power at the output port is equal to each other. It can be expressed as follows [7]:

$$\textit{Insertion loss, IL} = 10 \log \frac{P_{out}}{P_{in}} \tag{2.14}$$

Another important parameter is the insertion loss, S_{21}. It is indicate that the wave transmitted from port 1 to port 2. S_{21} is a forward transmission gain with the output port terminated at a matched load. The magnitude of insertion loss should be approaching to zero which means the signal measured at port 2 will approximately equal to injected signal at port 1. The equation is defined as in Eq. . Figure shows the ideal S_{11} and S_{21} in dB.

$$Insertion\ loss = S_{11} = 20 \log|S_{11}| \text{ in dB} \tag{2.15}$$

2.2.4 Matching properties

Impedance matching shows that the minimum reflection happened at each port. The network is matched if the coefficient $S_{ab} = S_{ba}$when i = j. For reciprocal network, [S] matrix symmetry and $S_{ab} = S_{ba}$. Thus, there is no loss of power, network is loss less and matched at all ports. The [S] matrix can be written as [7]:

$$[S] = \begin{bmatrix} S_{11} & S_{12} & S_{13} & S_{14} \\ S_{21} & S_{22} & S_{23} & S_{24} \\ S_{31} & S_{32} & S_{33} & S_{34} \\ S_{41} & S_{42} & S_{43} & S_{44} \end{bmatrix} \tag{2.16}$$

2.2.5 Bandwidth

The operational bandwidth is one of the important parameters in power divider. The bandwidth allows to determine the performance of the device under the desired frequency range. The percentage of bandwidth can be determined by [7]:

$$Bandwidth = \frac{f_{H-}\, f_L}{f_C} \text{ x } 100\ \% \tag{2.17}$$

F_H, f_L, f_C are higher cut-off frequency, lower cut-off frequency and central frequency respectively.

CHAPTER 3

METHODOLOGY

3.1 Introduction

In this chapter describes, in brief about the design procedure and fabrication process of Hybrid Ring Coupler. Basically, the process of this project involved the software and hardware implementation. Firstly, some parameters of the microstrip line, dielectric material, substrate and ground are set. The example of parameters are such as width, *w*, length, *l*, height, *h*, thickness of the substrate, *t.* For a software implementation, Computer Simulation Technology (CST) are choose to design Hybrid Ring Coupler.

As mentioned above, CST is used to design Hybrid Ring Coupler's 3D diagram and simulate it. It also used to analyzed and measure the S-Parameters of the design. The requirements of S-Parameters have been explained in Chapter 2. CST enables the user to determine the isolation loss and its resonant frequency behavior.

Furthermore, after the proposed design simulation has met the requirement, the generated design will be used for PCB fabrication process. The design methodology will be shown in Figure 3.1.

The simulation result of compact planar hybrid coupler ring coupler has been optimize and tune until get a good result of return loss, isolation loss and insertion loss. Table 4.1 shows the ways to optimize the proposed design until get good result.

Table 3.1: Optimization and tuning of compact planar hybrid ring coupler with embedded meander line

Optimization and Tuning	Effect
Increase the length of meander between port 1 and port 2	The return loss will shift to the lower frequency
Decrease the length of meander line between port 1 and port 2	The return loss will shifted to the higher frequency
Compact the size of ring	• The return loss shows more accurate at 2.4GHz • The isolation loss and insertion loss will decrease the value of dB
Increase the length of meander line between port 1 and port 3, port 2 and port 4	The return loss will decrease the value of dB
Increase the length of meander line between port 3 and port 4	• The return loss will shifted to higher frequency • The isolation loss and insertion loss also shifted to the higher frequency

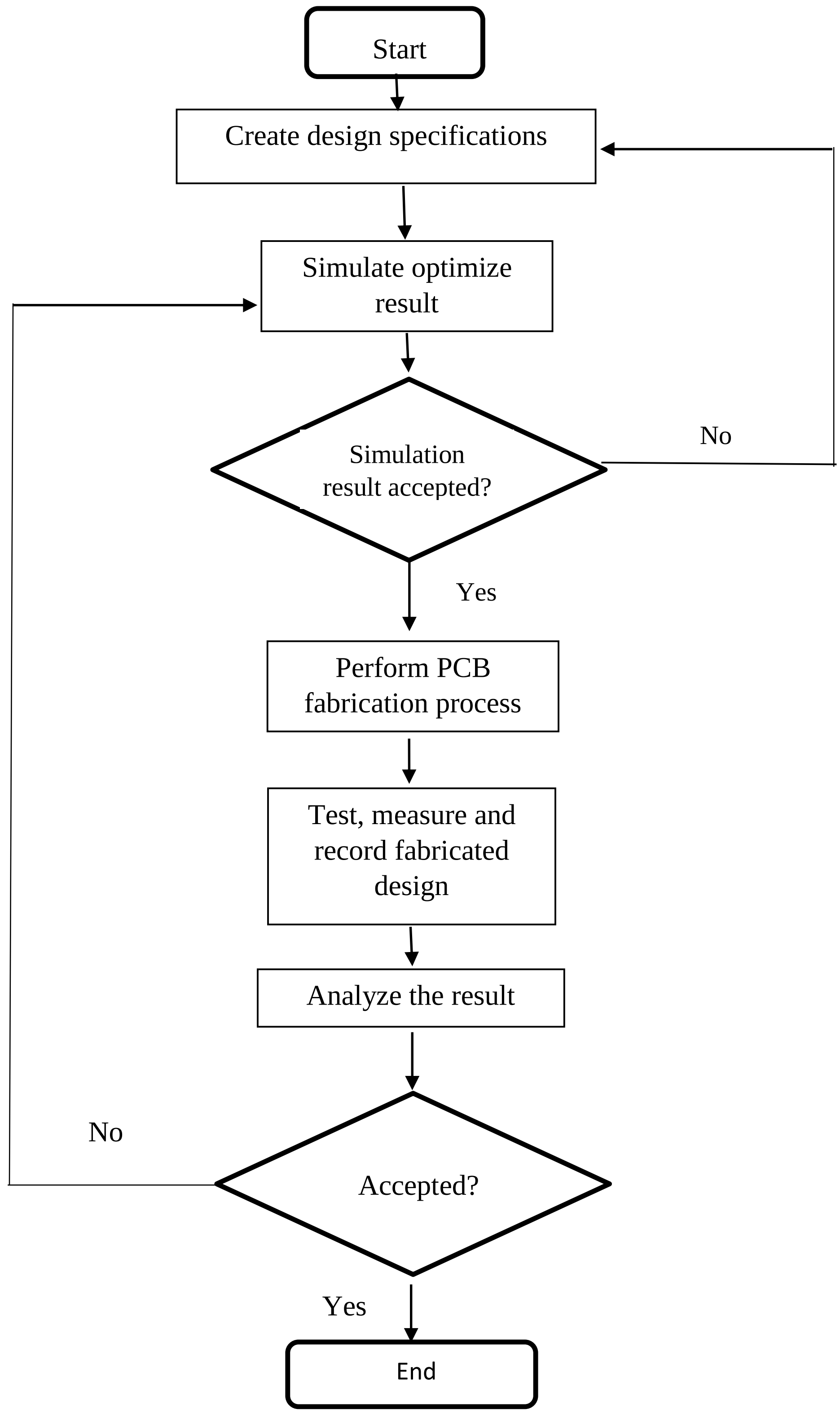


Figure 3.1: Flowchart of Hybrid Ring Coupler

3.2 Design Requirements and Specifications

To obtain a good performance of hybrid ring coupler with embedded meander line, there are several requirement for the design that need to be met. The requirements are the return loss, isolation loss, insertion loss, bandwidth, size and the coupling factors. For return loss, the reflected loss should be less than -10 dB. If the value obtained is less than -10 dB, it will indicate that there is less reflected output power to the transmitter. However, the isolation loss is also the same with return loss. Insertion loss shows the signal that passes through the device. Therefore, to have a good signal of the hybrid ring coupler, the insertion loss should be -5 dB. Bandwidth indicates the amount of data that can be transmitted to the receiver. Therefore the higher bandwidth for any application. In this project, the size reduction is influenced by the design of the meander line and the ring coupler which help to stabilize the performance so that it can operate at the central frequency of 2.4 GHz. Table 3.1 shows design specifications used in this project.

Table 3.2: Table shows design specifications used in this project

Design Specifications	
Operating Frequency	2.4 GHz
Return Loss, S_{11}	< -10 dB
Insertion Loss, S_{12}	< -5 dB
Dimension	80 mm x 80 mm

3.2.1 Conventional Ring Coupler Design

Firstly, a hybrid ring coupler is chosen because it has better in terms of low production cost than other techniques, good return loss and isolation performances and its reduce the costs. The purpose of designing this basic ring coupler is because to compare with hybrid ring coupler with embedded meander line. The dimension of this design is 240mm x 240mm

3.2.2 Compact Planar Hybrid Ring Coupler with Embedded Meander Line

In this project, embedded meander line is chosen as a method to compact transmission line due to its small layout area which enabled a reduction of device size. Figure 3.3 shows the design layout of the compact planar hybrid ring coupler with embedded meander line. CST tool is used to design and simulate the ring coupler and the hybrid ring coupler with embedded meander line operating at 2.4 GHz. The dimension of this design 80mm x 80mm.

The parameters are needed to determine the resonant frequency of compact planar hybrid ring coupler with embedded meander line. In this project, RO 4003C is used as the substrate material Copper annealed are used for the ground material. However, for the ring coupler design also used copper annealed. Therefore, Table 3.1 is constructed.

Table 3.3: Table shows the parameters used to design compact planar hybrid ring coupler with embedded meander line

Parameters	Value
Dielectric Constant, ε_r	3.55
Thickness of Copper, *t*	0.035 mm
substrate, *H*	0.81 mm
Width for meander line, *Wm*	0.81 mm
Width for port, *Wp*	3.24 mm

The width for the microstrips transmission line is calculated to be 1.62 mm using the following formula:

$$\frac{w}{h} = \frac{377}{\sqrt{\varepsilon_r}} - 2 \qquad (2.18)$$

The width of the meander line is halved from the width of the transmission line, which is 0.81 mm.

The design of compact planar hybrid ring coupler with embedded meander line is optimized and the size of the design is reduced 66.67% the dimensions of the conventional ring coupler. Figure 3.4 shows the size reduction of compact planar hybrid ring coupler with embedded meander line from the conventional ring coupler.

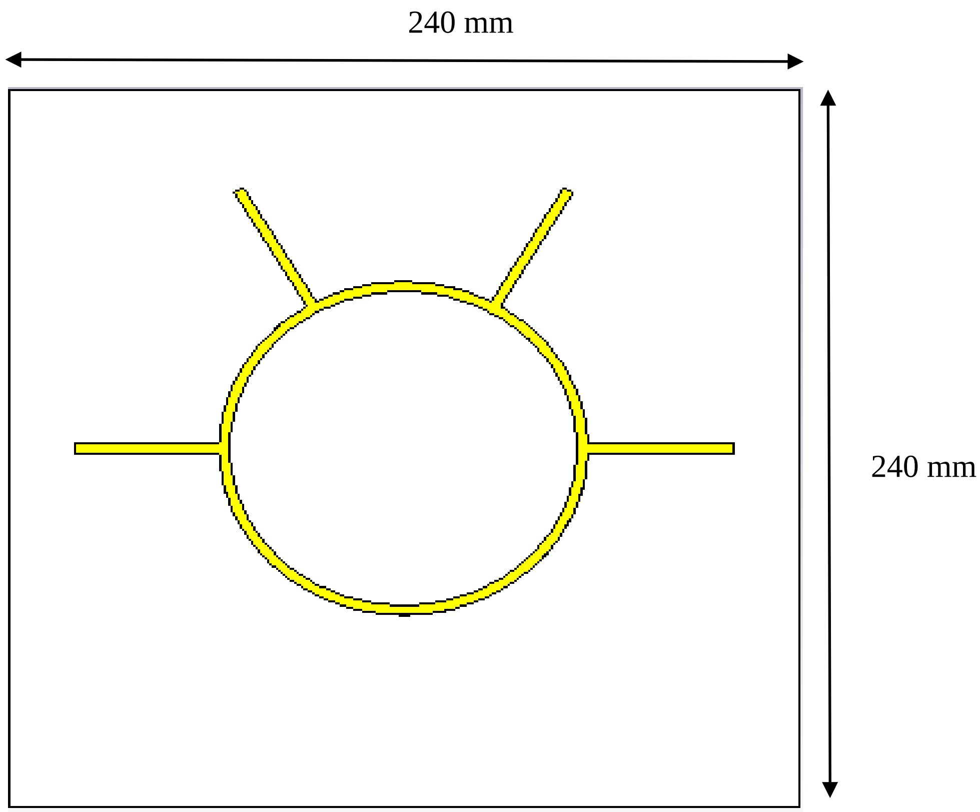


Figure 3.2(a): Conventional Ring Coupler

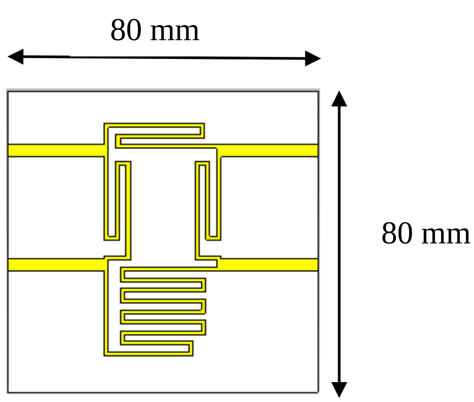


Figure 3.2(b): Compact Planar Hybrid Ring Coupler with Embedded Meander Line

Figure 3.2: Size comparison of the (a) conventional ring coupler and (b) compact planar hybrid ring coupler with embedded meander line