

ACTIVE INTEGRATED ANTENNA  
WITH SIMULTANEOUS TRANSMIT AND RECEIVE

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*“To my beloved Father, Mother, Sister and wife”*

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## ABSTRACT

An active antenna with simultaneous transmit and receive function, integrate an active devices onto a printed antenna to improve its performance or combine functions within the antenna itself. Such antenna are of increasing interest, as system designers require more complex functions to be implemented in reduced space. This paper discusses the integration of active antennas by combining both transmit and receive functions into one single antenna. Four main components in the design are circular polarized microstrip patch antenna, rat race coupler, power divider and amplifiers. All the simulations are done using the Agilent ADS. The circular polarized antenna resonates at 2.4 GHz. Two MESFET amplifiers have been used to transmit and receive the channel separately. The rat race coupler isolates the two channels and a Tee junction power divider is connected the two channels to the input and output port. The channels are of the same frequency. The simulation and measurement results of the microstrip patch antenna for  $S_{11}$  are lower than -10 dB at frequency of 2.4 GHz. The antenna polarization is confirmed as a circular polarized, as can be seen in the radiation pattern from the measured and simulated results. The amplifier biasing circuit is supplied by two power sources; one is the drain voltage ( $V_{ds}$ ) which is positive and the other is the gate voltage ( $V_{gs}$ ), which is negative. After integrating all of the components, the radiation pattern is measured for both transmit and receive. The beamwidth of the antenna is in the range of  $60^\circ - 70^\circ$  for H plane. The radiation pattern for E plane is smaller compared with the H plane. The comparison between the passive and the active integrated antenna shows that the active integrated antenna has 3 dB extra gain compared to the passive antenna for both transmit and receive. The isolation between transmit and receive is between 20 – 25 dB.

## ABSTRAK

Sebuah antenna aktif yang memiliki fungsi serentak ‘menghantar’ dan ‘menerima’, disepadukan dengan komponen-komponen aktif untuk meningkatkan prestasi dan fungsi dalam antenna itu sendiri. Minat terhadap antenna yang memiliki ciri-ciri ini bertambah, dimana para pereka system memerlukan fungsi-fungsi kompleks bersepadu dalam ruang yang kecil. Thesis ini membincangkan tentang integrasi antenna aktif, dimana kedua-dua fungsi ‘menghantar’ dan ‘menerima’ digabungkan dalam satu antenna. Empat komponen utama dalam rekabentuk ini termasuklah sebuah antenna microstrip tampal yang berpolarisasi keliling, Gandingan Rat Race, pembahagi kuasa dan amplifier. Kesemua simulasi dibuat menggunakan software Agilent ADS. Antenna yang berpolarisasi keliling bergema pada frekuensi 2.4 GHz. Dua unit amplifier ‘MESFET’ telah digunakan untuk menghantar dan menerima saluran (channel) secara berasingan. Gandingan ‘rat race’ pula memisahkan kedua-dua saluran ini manakala sebuah pembahagi kuasa berbentuk ‘Tee’ disambung kepada kedua-dua saluran pada port masukan dan port keluaran. Kedua-dua saluran beroperasi pada julat frekuensi yang sama. Data daripada keputusan simulasi dan pengukuran untuk antenna mikrostrip tampal ini menunjukkan julat  $S_{11}$  yang rendah dibawah -10dB untuk frekuensi 2.4GHz. Polarisasi antenna adalah disahkan berpolarisasi keliling sepertimana dapat di lihat dalam keputusan penyinaran daripada simulasi dan pengukuran. Pincangan litar penguat adalah dibekalkan oleh dua kuasa sumber; satu daripadanya ialah voltan parit ( $V_{ds}$ ) yang merupakan punca dan satu lagi ialah voltan get ( $V_{gs}$ ), yang merupakan punca negatif. Selepas semua komponen disepadukan, bentuk pancaran diukur untuk penghantaran dan penerimaan. Lebar alur antenna berada dalam julat 60o – 70o untuk satah H. Bentuk pancaran untuk satah E adalah lebih kecil dibandingkan dengan satah H. Perbandingan di antara antenna pasif dan antenna aktif bersepadu, menunjukkan bahawa antenna aktif bersepadu mempunyai gandaan 3dB lebih berbanding dengan antenna pasif untuk kedua-dua penghantaran dan penerimaan. Pengasingan di antara penghantaran dan penerimaan adalah di antara 20 – 25 dB.

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# CHAPTER 1

## INTRODUCTION

### 1.1 Introduction

The active integrated antenna (AIA) has been a growing area of research in recent years, as the microwave integrated circuit and monolithic microwave integrated circuit technologies became more mature allowing for high-level integration. From a microwave engineer's viewpoint, an AIA can be regarded as an active microwave circuit in which the output or input port is free space instead of a conventional  $50\text{-}\Omega$  interface. In this case, the antenna can provide certain circuit functions such as resonating, filtering, and duplexing, in addition to its original role as a radiating element. On the other hand, from an antenna designer's point-of-view, the AIA is an antenna that possesses built-in signal and wave-processing capabilities such as mixing and amplification. A typical AIA consists of active devices such as Gunn diodes or three-terminal devices to form an active circuit, and planar antennas such as dipoles, microstrip patches, bowties, or slot antennas.

Looking back in history, the idea of using active antennas can be traced back to as early as 1928 [1]. At that time, a small antenna with an electron tube was commonly used in radio broadcast receivers around 1 MHz. After the invention of

high-frequency transistors, the study of active antennas received much more attention and several pioneering works were reported in the 1960s and 1970s. Several advantages of implementing the active devices in passive radiating elements were discussed in [2]. For instance, these works include increasing the effective length of short antenna and increasing antenna bandwidth, decreasing the mutual coupling between array elements, and improving the noise factor. Over the past decades, the major driving forces for the research on AIA are the development of novel efficient quasi-optical power combiners. The original purpose for the quasi-optical power combining is to combine the output power from an array of many solid-state devices in free space to overcome combiner loss limitations, which are significant at millimeter-wave frequencies. Rather, this paper reviews more on the functional performance of individual AIA. Recently, numerous innovative designs based on the AIA's concept have been proposed and successively demonstrated. AIA technology has evolved to a point where practical implementation for use in the latest microwave and millimeter-wave system is considered feasible. It is currently pursued in a number of related fields such as power combining, beam steering and switching, retro directive arrays, as well as high-efficiency power-amplifier designs. These AIA-based designs are particularly attractive for millimeter-wave systems because they provide an effective solution to several fundamental problems at these frequencies, including higher transmission-line loss, limited source power, reduced antenna efficiency, and lack of high-performance phase shifter. This paper reviews the recent research activities related to this emerging technology with emphasis on its applications in integrated antenna, amplifier.

An active antenna with simultaneous transmit and receive integrates an active device into a printed antenna to improve its performance or combine functions within the antenna itself. Such antennas are of increasing interest [3] as system designers require more complex functions to be implemented in reduced space. New high-volume millimeter applications such as vehicle collision avoidance radar, wireless local-area networks (WLAN), and electronic tagging are driving costs lower and putting further constraints on size and weight. This paper hopes to take further steps in the integration of active antennas by combining both transmit and receive functions into a single antenna. This paper uses a circular polarized microstrip-patch antenna resonant at 2.4 GHz, with two metal–semiconductor field-effect transistor

(MESFET) to form two amplifiers used in transmit and receive channel separately, one Rat-Race Coupler isolated the two channels and one T-junction Power Divider connected the two channels to the input and output port. The channels are of the same frequency.

## **1.2 Problem Statement**

The problem statement of this project is stated in the follow: An antenna with good gain and integration of transmit and receive for the indoor WLAN in 2.4 GHz band is required. Theoretical results are obtained to satisfy good return loss and gain requirements and isolation between transmit and receive channels for the active antenna with simultaneous transmit and receive, but the practical result is still big challenge to be verified, this project will prove that down-to-earth.

## **1.3 Objective**

The objective of this project is to design, simulate, fabricate and test a simultaneous transmit–receive active antenna at the frequency of 2.4 GHz, which is attractive for potential uses in WLAN communication.

## **1.4 Scope of Research**

1. To design a circular polarized microstrip patch antenna at 2.4 GHz;  
To design a Rat-race Coupler at 2.4 GHz;  
To design an Amplifier's Biasing circuit at 2.4 GHz;  
To design a T-junction Power Divider at 2.4 GHz;  
To combine all these parts above and design an Active Integrated Antenna with Simultaneous Transmit and Receive at 2.4 GHz.

- 2 The antenna specifications include parameters such as frequency, bandwidth, and all theoretical investigations.
- 3 To simulate all these designs until reach the best result using Microwave Office and Agilent ADS software.
- 4 The prototype will be fabricated with the available microstrip materials (FR4) based on the simulation and using wet etching technique.
- 5 All the fabrication will be tested in Lab and test bed as a field trial to measure their performance.
- 6 The comparison between measurement results and simulation results.
- 7 Analyzing the results and writing up thesis.

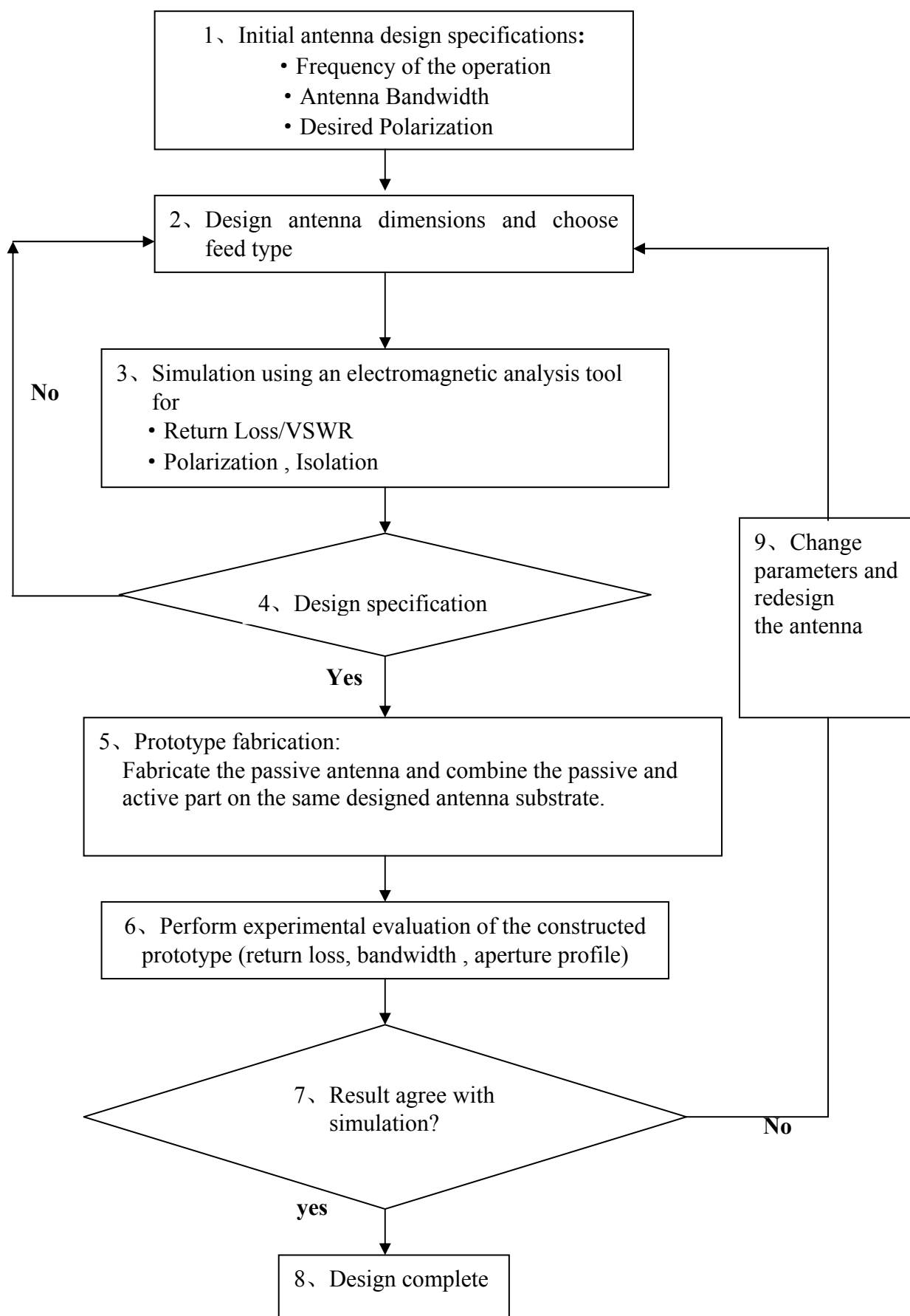
### **1.5 Research Methodology**

A theoretical and experimental design approach was utilized to optimize the antenna structure, the strategy implemented for simplifying the design and development procedures in this research work can be divided into the following points:

1. Initial concept
  - Literature review
  - Problem statement
  - Design conceptual understanding
2. Design and simulation stage
  - Design consideration based on previous research results
  - Decide the input parameters of the antenna
  - Design the passive part of the antenna using antenna design software (Microwave Office and Agilent ADS).
  - Do simulation for the whole antenna design using antenna design software (Microwave Office and Agilent ADS).
3. Prototype stage
  - Fabrication of the passive part of the designed antenna

- Combining the passive and active part of the proposed antenna
4. Measurement stage
    - Do measurement of the properties of the fabricated antenna
  5. Analysis and conclusion stage
    - Do comparison between measurement results and the simulation results and draw a conclusion
  6. Collect results and produce papers

The antenna fabrication needs to fit within the costing constraints and the availability of materials. The design and development procedures are briefly summarized in the following chart **Figure 1.1** in particular, this methodology provides an approximate chronological progress of the work performed to finally complete the full design cycle.



**Figure 1.1** Flow chart representing of AIA with Tx & Rx function





Applications and V.B. Erturk's Design/Analysis of an Active Integrated Antenna.

Chapter 3: This chapter discusses the theory and equation needed to design this AIA and its components. This chapter also presents the design, simulation and fabrication of every components and final AIA in detail and presents the simulation results.

Chapter 4: This chapter presents the setting up of different measurement separately, it includes the setting up for biasing circuit testing, setting up for radiation pattern and gain measurement and setting up for power strength measurement.

Chapter 5: This chapter discusses and analyzes the results of antenna prototype measurement compared to the simulation result. The antenna application in the real environment and comparison with monopole also presents in this chapter.

Chapter 6: This chapter presents the conclusion based on the analysis and comparison of results in chapter 5. Recommendations for future works are also presented.

## **1.8 Summary**

Brief introduction on project and its objective have been presented. Its scopes has also been presented to give a clear view on the direction of this project. The methodology and outline of this thesis have also been described.