LOW NOISE ACTIVE INTEGRATED ANTENNA (LNAIA)

Oleh

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ABSTRACT

Nowadays, the developments of wireless communication fields are widely used. One of them is the usage of the antennas in data transmission between the receive antenna and the transmit antenna. Active Integrated Antenna (AIA) is a new technology that integrates the passive antenna element with active device in a single substrate. In this project, an inset feed microstrip patch antenna is integrated with a Low Noise Amplifier (LNA) to produce an AIA system. The purpose of this project is to investigate in terms of active and passive performance of the antenna. Indeed, this microstrip patch antennas are known to be easy to be integrated with active devices. This microstrip patch antennas will directly be integrated to the transistor, producing gains and low noise. Commonly, antennas that have been designed are not integrated directly to the active devices, causing high noise but with the AIA approach it could reduce the losses. This Low Noise Active Integrated Antenna (LNAIA) is resonated at 2 GHz that used transmission line feeding method with impedance matching at 50 ohm. The matching technique is important in designing the LNA. Besides that, this AIA's have many advantages such as less cost, smaller size and good for radiation characteristic for microwave wireless communications.

ABSTRAK

Perkembangan bidang komunikasi tanpa wayar semakin meluas digunakan pada masa kini. Salah satu daripadanya ialah penggunaan antena dalam penghantaran data di antara antena pemancar dan antena penerima. Antena Aktif Bersepadu (AIA) merupakan satu teknologi baru yang menyepadukan elemen antena pasif dengan peranti aktif di dalam satu substrate. Di dalam projek ini, Antena Aktif Bersepadu iaitu antena tampal mikrostrip suapan sisipan disepadukan dengan penguat hingar rendah. Projek ini bertujuan untuk menyiasat keadaan sistem prestasi antena di dalam keadaan aktif dan pasif .Antena tampal suapan sisipan segiempat adalah dalam keadaan pasif manakala penguat hingar rendah adalah dalam keadaan aktif. Antena tampal mikrostrip ini sememangnya dikenali mudah untuk disepadukan dengan komponen aktif. Antena tampal mikrostrip ini akan disepadukan terus ke transistor untuk menghasilkan gandaan dan berhingar rendah. Lazimnya antena yang direkabentuk tidak disepadukan terus dengan komponen aktif yang menyebabkan hingar yang tinggi, tetapi dengan pendekatan Antena Aktif Bersepadu boleh mengurangkan hingar. Antena Aktif Bersepadu ini berfungsi pada frekuensi 2 GHz iaitu dengan menggunakan teknik suapan talian penghantaran dengan kesepadanan impedan pada 50 ohm. Teknik pemadanan amat penting dalam merekabentuk penguat berhingar rendah. Di samping itu, Antena Aktif bersepadu ini mempunyai banyak kelebihan seperti menjimatkan kos, saiz yang kecil dan mempunyai kebaikan dari segi ciri penyinaran untuk komunikasi tanpa wayar mikro gelombang.

CHAPTER 1

INTRODUCTION

1.1 Overview

The microstrip antenna is now an established kind of antenna that is confidently prescribed by designers worldwide [12]. In high-performance aircraft, spacecraft, satellite and missile application, where size, weight, cost, performance, ease of installation and aerodynamic profile antenna may be required.Generally the advantages of using micro strip antenna are low profile,conformable to planar and non planar surfaces, simple and inexpensive to fabricate using modern printed circuit technology, mechanically robust when mounted on rigid surface, compatible with MMIC designs, and very versatile in terms of resonant frequency, polarization, pattern and impedance [9].

The main disadvantages of microstrip antenna can be divided into three major factors.The first factor is narrow bandwidth (5% to 10% [2:1 VSWR] is typical without special technique).The second factor is the dielectric and conductor losses can be large for thin patches resulting in poor antenna efficiency and the last main disadvantage is the sensitivity of microstrip antenna to environment factors such as temperature and humidity [1].

Active integrate antenna (AIA) approach combines the antenna and active platforms into one highly integrated system. AIA systems have several unique features [12]. AIA is one of the effective techniques to reduce noise and can provide high gain. Further more AIA can reduce the fabrication cost, greater efficiency and smaller size compared to conventional design.

For this project, the LNA is proposed to be integrated to a passive antenna that could produce high gain and low noise performance at the front-end receiver. This can be accomplished by using a new modern technology of active component such as PHEMT FET. This FET will give low noise figure typically at 12 GHz is 0.5 dB while at 4 GHz the noise figure is 0.3 dB. Thus, this active component can be used to reduce noise problem and making the area of active integrated antenna to be re-investigated.

1.2 The Objectives of the Project

The purpose of this study is to determine and investigate in terms of integrating the passive (antenna) and active system (LNA) as a front-end receiver. Micro strip patch antennas are known for its ease of integration with active devices. Such application is in the system amplification where the antenna is directly integrated to the FET producing gains and low noise. The low noise amplifier will be designed at 2 GHz, using Hewlett-Packard's ATF-36077. This transistor is an ultra-low-noise Psedomorphic High Electron Mobility Transistor (PHEMT) packaged in a low parasitic surface mountable ceramic package whereas the antenna will be designed as an inset fed antenna using microstrip. The LNA will be integrated directly to the inset fed antenna.This integration is achieved at 50 ohm characteristic impedance.

1.3 Report Organization

There are 8 main chapters on this final year report. The first chapter can be divided for two sections, introduction and the main objective of the project. The second chapter is based on to literature review that is related to the project aim.Among the sub chapters are the introduction of AIA, design methodology, measurement issues, classification of AIA, AIA applications and finally an example of AIA that has been done. This chapter covers the patch antenna design and low noise amplifier design. Next is Chapter 3, emphasis more on microstrip patch antenna theory in general. This chapter will cover on the introduction, advantages and disadvantages of microstrip antenna and feeding method. Next sub topic is about method of analysis which used the transmission line model. Chapter 4 is about Low Noise Amplifier design. Important procedures are explained including the design consideration, device choice and characteristic, amplifier design, stability analysis, gain calculations, matching circuits, constant noise circle, dc biasing, results and LNA calculations. Chapter 5 will discuss about inset fed micro strip patch antenna. There are six sub chapters in this chapter. This chapter covers the introduction, theory, patches antenna design, results and analysis, far field radiation pattern and lastly is radiating slot for inset fed antenna. Next is Chapter 6 that emphasis more on AIA design that covers introduction, AIA procedure and result & analysis. AIA is giving a better result in improving gain and noise figure as well. Further more AIA will increase the antenna efficiency, good in radiating and reduced cost.

Fabrication, testing and measurement process is explained Chapter 7. This chapter is to determine whether simulation test result and hardware fabrication result is nearly close to the real specification. This chapter covers introduction, fabrication, testing and measurement of the systems. Among its sub chapters are fabrication of the LNA, inset fed micro strip patch antenna and the Low Noise Active Integrated Antenna (LNAIA). Besides that the S-parameters measurement also will be discussed in depth for all hardware fabrication as mentioned above. An investigation will be observed in terms of gain and noise. Finally Chapter 8 will conclude the overall of this AIA project.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Active Integrated Antenna (AIA) has been 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 [4]. AIA approach combines the antenna and active platforms into one highly integrated system. The inclusion of active, nonreciprocal devices means that the AIA system is typically nonreciprocal, unlike passive antenna. Therefore, AIA's often function as their transmitting or receiving class antennas. Several classes, notably the recently developed AIA retrodirective array, defy classification and function simultaneously as a transmit and receive antenna. While this may seem an obvious or trivial fact, it does have some important ramifications, most notably in AIA architectures and measurement methodology [11].

In the point of view from a microwave engineer's an AIA can be classified as an active microwave circuit in which the output or input port is free space instead of a conventional 50 ohm 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, micro strip patches, bowties, or slot antennas [4].

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 shifters [21].

The advantages of AIA for applications in microwave and millimeter-wave integrated transceivers in wireless system is well known [21]. Among the advantages of AIA are high performance, low cost, low profile, minimum power consumption and a high degree of multiple functionality.

2.2 Design Methodology

Based on to the current abilities of microwave computer-aided design (CAD) tools and EM simulators, single pass design success is required when designing highly integrated AIA modules. This is highly desirable for more than the obvious reason that it speeds up the design and the prototyping process. Otherwise another reason is the difficulty in performing manual tuning of AIA modules since the antenna and active circuitry are integrated together. Hence, the designer must test the whole module in anechoic chamber, rather than testing the active circuitry separately from the antenna since the antenna and active circuitry are integrated together. Generally antenna measurement can be time consuming [11].

Further more, for global simulation of microwave circuits, combining both active circuitry and full-wave analysis in one concurrent simulation have been reported successfully but this technique is still prohibitively slow on today’s personal computer [2, 18]. Hence it would be highly interest that the whole microwave/millimeter wave engineer in global could use one global simulation CAD tool that would intrinsically treat such EM phenomena as radiation and coupling. This can be the same as non linear effects such as gain and mixing. It would be necessary that this task could be performed in a short time frame that circuit optimization would be feasible [11].

At this time, the most effective technique for AIA design is to first optimize the antenna structure in term of the total module such as radiation properties and input impedance. Then, either measured or simulated S-parameter measurements of the optimized antenna structure are incorporated into a commercial microwave CAD tool that can accurately predict nonlinear effects such as Agilent’s Series IV. Besides that the designer can optimize performance with the same efficiency as achieved by a more conventional topology. This process may require additional iterations of antenna design to achieve required specifications for the module [11]. However this technique is not essentially different from that used by millimeter wave designers are typically verifying that EM effects have not irretrievably compromised their designs, whereas the AIA designer relies on EM on effects for the fundamental performance of the circuit. For many AIA applications, accurate S-parameters are required over a broad band bandwidth [11].

2.3 Measurement Issues

AIA measurements can be performed by using anechoic chamber for all usual equipment for testing active topologies. Testing AIA module can be quite tedious than testing either active circuitry or antennas. However, the basic technique is straightforward and consists of the logical merging of the typical active measurement techniques. A typical experiment setup for measuring amplifier AIA transmitter is shown in Figure 2.1.The fundamental concepts can be modified to other types of AIA modules such as AIA oscillators, mixers and receiver. To relate this, one of the most useful equations for calculation is Friss transmission formula which is given in equation 2.1 [14].

$$P_{rec} = \frac{P_{trans} \times G_t \times G_r \times \lambda^2}{(4\pi R)^2} \tag{2.1}$$

where ;

Prec = Power of receive antenna

Ptrans = Power of transmit antenna

G t = Gain of transmitter

G r = Gain of receive antenna

λ = Free space wavelength

R = Distance between transmit and receive antennas

The AIA gain can be determined using Equation 2.1 since all parameter values are known. Since large signal operation is of important in power amplifier measurement, the network analyzer typically is found in anechoic chambers is replaced with a source capable of powering the AIA and a spectrum analyzer. A dc power supply must be included to power the module [11].

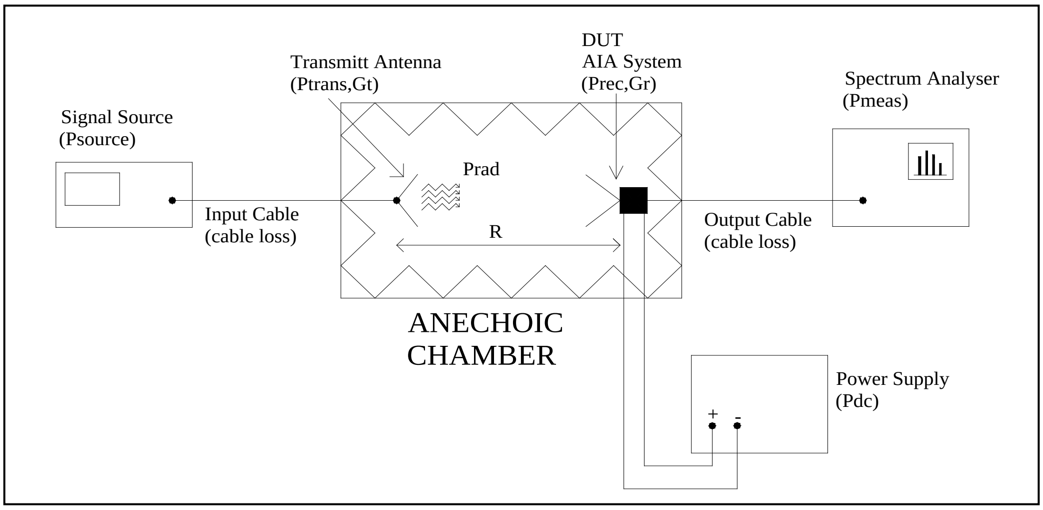


Figure 2.1: Typical experimental set up for AIA amplifier module [23]

2.4 Classification of AIA

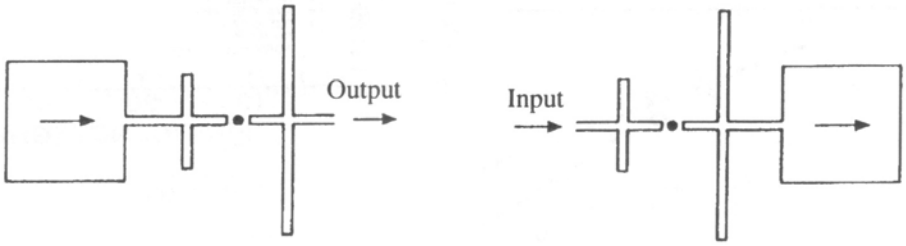
Active integrated antenna can be classified by the function of active devices they integrate [23]. The RF signal amplification, frequency conversion or RF signal generator is the basic functions of the devices in active integrated antennas [23]. Based on the function of the active device, the active integrated antennas can be classified to three types. There are oscillator types, the frequency conversion type and lastly is the amplifier type. Transmitting and receiving are kind the two basic of active integrated antennas. Transceiver, transponders, repeater are some examples of kind that have operation, transmitting and receiving microwave frequency signal. Besides that, an amplifier can be integrated to antenna elements at its input port as transmitter or at its output port as receiver. Fortunately it also can be integrated to antenna elements at both ports to function as repeaters. All these combination have common feature such the integration between an amplifier and antenna elements [15].

The purpose of classifying active integrated antennas is to classified them to their different functions of active device that their integrate. Semiconductor devices can be defined as active device or active component. The active component can be applied for rectification, amplification or to change energy from one to another [23]. Basic active circuits such as oscillators, amplifiers, mixers and multipliers are employing active devices with above function [15]. The active devices in these circuits are act by amplifying the RF signal, generate the RF signal or to convert the signal to different frequencies. Therefore the basic functions of active circuits are oscillating, amplifying and frequency converting [15]. These three types of active integrated antennas probably are investigated further to have complex functions is a single module [15]. For this project amplification type will be more emphasized to investigate.

2.4.1 Amplifier Type

Amplifier type can be classified by looking at the integration of a two port active device with passive element at the input port or at the output port for signal amplification. For example, when the antenna is feeding at the input port, it's considered to be source impedance for the device and the active integrated antenna acts as receiver [23].For considering noise figure, a Low Noise Amplifier (LNA) design technique is used. On the other hand, when the antenna is feeding at the output port, it's become as a device load impedance and active integrated antenna will be as a transmitter. Both of the receive and transmit active integrated antenna are shown in Figure 2.2 (a) and Figure 2.3 (b) respectively.

The advantages of implementing amplifiers in a passive antenna structure are increasing the antenna gain bandwidth and improve noise performance. The amplifier type of AIA modules can be integrated in an array structure to increase the power handling capability [23].Active micro strip antenna using FET's are compatible with microwave integrated circuit (MIC) and monolithic integrated circuit (MMIC) technologies. It's allows for easy integration that leads to compactness and potentially low costs of fabrication [23]. In fact, amplifier type of AIA is now expanding and growing positively because of its potential application in many communication field, besides in a large phase array and in spatial power combining amplifier.



(a) Receive antenna **(b) Transmit antenna**

Figure 2.2: Amplifier type active integrated antenna [23]

2.5 AIA Application

2.5.1 Introduction

AIA's give another way for designing modern microwave and millimeter wave architecture with desirable features such as compactness, low cost, minimum power consumption, light weight and multiple functionality [22]. Historically, the concept of the AIA was proposed and employed in the design of quasi-optical mixers to eliminate lossy and bulky interconnect between the active device and antenna or taking full advantage of some intrinsic properties of the antenna such as polarization duplexing [22].

Nowadays, several creative and innovative designs based on the AIA concepts have been proposed and successfully demonstrated in many microwave and millimeter wave application system including high efficiency transmitters and low noise receivers, various up converters and down converter, quasi-optical mixers and power combining arrays as well as various types of wireless sensors. Normally AIA based designs are particularly attractive for millimeter wave systems because they provide an effective solution for several fundamentals problems such as transmission line loss, limited source power, reduced antenna efficiency and lack of high performance phase shifts [22].

2.5.2 A Novel Proximity Coupled Active Integrated Antenna [21]

This novel design approach is applied for AIA application. Basically A Novel Proximity Active Integrated Antenna (PCAIA) is a new type of antenna feed structure is proposed. A single self-biased through RF port, two-stage low noise amplifier has been integrated with proximity coupled patch antenna having a new feed structure. This approach is useful in the design of compact PCAIA with good radiation characteristics for application in microwave wireless systems.

Integration of the active circuitry and the microstrip patch antenna using the basic feeding techniques on a single substrate will not achieve compact circuit size and good radiation characteristics. Besides that, the patch antenna need a low ε_r, thick substrate for good radiation characteristics, whereas the RF circuitry requires a thin, high ε_r substrate for size reduction and low radiation loss. Proximity coupled (PC) patch antennas, due to their multilayer architecture, provide a solution for developing a thin and compact feed network without compromising the antenna performance. This type of patch antennas is reported to have achieved higher bandwidths compared to other feeding techniques. However, no reports have demonstrated a PC patch antenna with the feedline on very high ε_r (>5) and thin (h<50 mil) boards due to the inadequate coupling between the conventional 50Ω feedline and the patch antenna on these boards. A modified feedline approach on a high ε_r and thin board for use in the PC patch antenna configuration is necessary. In the AIA presented here, a PC patch antenna is integrated with a two-stage GaAs FET LNA. A new type of feedline has been developed to achieve better radiation characteristics for the patch antenna, using a very high dielectric constant (ε_r=9.2) and thin (h=30mil) substrate for the feedline and LNA. The active antenna is biased through the RF port. The PCAIA design approach and measured results are presented in the following sections.

2.5.3 Proximity Coupled(PC) Patch Antenna Design [21]

The geometry of the new proximity coupled active integrated antenna with a widened feedline is shown in Figure 2.3. The widened feedline increases the capacitive coupling between the patch radiator and the feedline, hence improving the radiation characteristics of the antenna. The substrates were chosen to achieve minimum LNA circuit size and good antenna radiation characteristics.

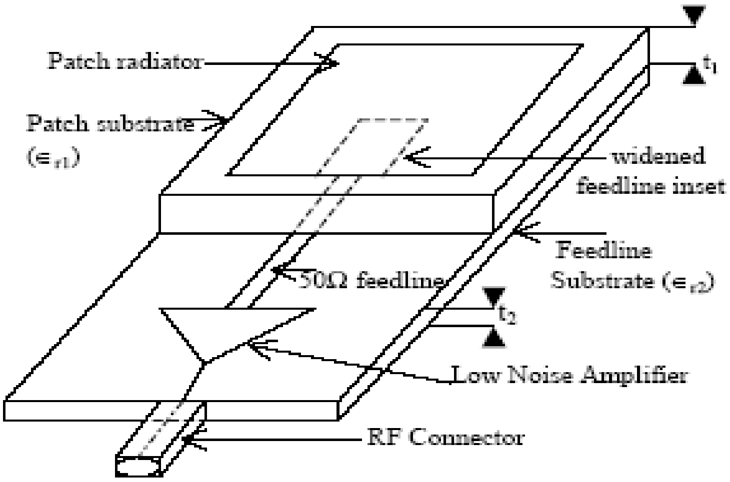


Figure 2.3: Geometry of the proposed proximity coupled Active Integrated Antenna (PCAIA) with widened feed line inset [21]

Various widened feedlines of characteristic impedances 50Ω, 40Ω, 30Ω, 20Ω, 10Ω, 8Ω, and 5Ω were fabricated to test the antenna performance. A feedline overlap of 50% with the patch antenna was considered. Table 2.1 summarizes the measured results for various widened feed line insets. Minimum return loss occurred for the feedline having 20Ω and characteristic impedance. The results also show that further widening of the feedline would make the effective feedline-antenna combination to resonate at a different frequency.

Table 2.1: Measured results of the PC Patch with widened feedline insets (50% overlap with patch)

Characteristic Impedance of the feedline inset (Ω)	**50**	**40**	**30**	**20**	**10**	**8**	**5**
Width of the feed-line inset(mil)	29.3	44.6	71.6	128	300	89	655
Resonant frequency of the PC patch(GHz)	1.8	1.8	1.8	1.84	1.84	1.84 and 1.5	1.48
Return loss of the PC patch (dB)	-2.0	-2.3	-3.9	-6.8	-3.4	-3.0	-3.5
Input impedance of the PC patch (Ω)	6+j12	8+j18	17+j32	38+j58	217+j95	282.-j53	12-j11
Input impedance point in Fig 2.4	A	B	C	D	E	F	G

Input impedances of the antenna with various feedlines at the resonant frequencies are shown on the smith chart in Figure 2.4. Points A, B, C, D, E, F, and G in Figure 2.4 correspond to the input impedances of the PC patch antenna with widened feedline insets of characteristic impedances 50Ω, 40Ω, 30Ω, 20Ω, 10Ω, 8Ω, and 5Ω respectively. It can be observed that the path traced by the points A-G in Figure 2.4 follows a regular pattern. This observed phenomenon could be further investigated to predict the optimum width of the feedline (20Ω feedline here) required to achieve the lowest return loss for a given PC patch antenna configuration.

The optimum feedline with 20Ω characteristic impedance was chosen for integration. The measured return loss of this patch antenna is shown in Figure 2.5. The input impedance of the antenna is 37.592+j57.66Ω at the resonant frequency (1.8388 GHz). This impedance was used as the source impedance in the design of the LNA.

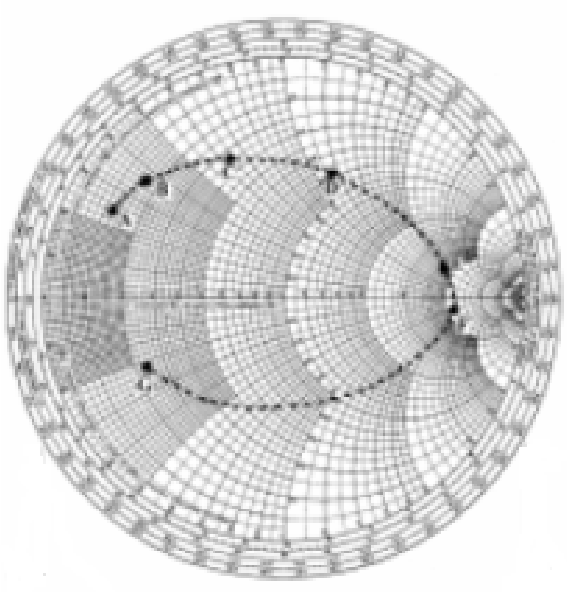


Figure 2.4: Measured input impedance of the proximity coupled patch with widened feed lines [21]

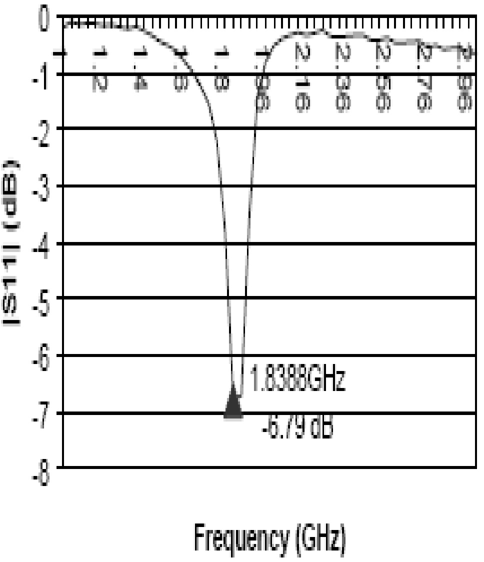


Figure 2.5: Measured return loss of the PC patch antenna with antenna 20Ω feedline inset [21]

2.5.4 AIA Low-Noise Amplifier Design [21]

The block diagram of the AIA consisting of an antenna and two-stage LNA is shown in A.1 (Refer to Appendix A). Unlike the conventional design approach where the antenna and the amplifier are first matched to 50Ω and then connected together, here the input impedance of the antenna is directly transformed to the source impedance needed for minimum noise figure. The DC and RF paths in the AIA are shown in Figure 2.6.The transistors are self-biased from a single DC source, through the RF port.

2.5.5 Bias Network and FET stabilization [21]

Figure A.2 (Refer to Appendix A) shows the self-biased FET configuration. The transistor used is NE34018, as it has good noise performance and gain. The stabilized self-biased transistor was simulated for S-parameters and noise parameters using

HPADS circuit simulator. The parameters of the stabilized self-biased transistor were used in the design of the LNA.

2.5.6 LNA Design [21]

The low noise amplifier was designed by implementing the matching networks as shown in Figure 2.6. Short circuited single stub matching networks were used. The input matching network was designed such that the input impedance of the antenna was transformed to Z_{NF}, which corresponds to the Γ_{opt} of the self-biased transistor. The inter-stage matching network was designed to transform the output impedance of the first stage to Z_{NF} to provide a noise match for the second stage. The output matching network transforms the output impedance of the second stage to 50Ω port impedance. Choke networks as shown in Figure 2.6 were provided to bias the FETs. The 50Ω input line of the amplifier was extended and widened (20Ω) to serve as the feedline for the PCAIA as shown in Figure 2.3. The amplifier circuit was simulated using HPADS for S-parameters and noise figure. The input port impedance (source impedance) was adjusted to be equal to the antenna input impedance (37.592+j57.66Ω). The simulated S-parameters and noise figure are shown in Figure A.3 and Figure A.4 respectively (Refer to Appendix A). It is evident from Figure 2.8 and Figure 2.9 that the LNA has a gain of 27.3dB, noise figure of 0.77dB, input return loss of –14.14dB, and output return loss of –15.8dB at the design frequency (1.8388 GHz).

2.5.7 Measured Results [21]

The PC patch radiator was fabricated on RT duroid 5870 and the AIA low noise amplifier was fabricated on TMM10i boards, both from Rogers Corporation. The radiator and the amplifier were properly aligned and attached. The AIA was mounted in a metal housing. The photograph of the PCAIA is as shown in Figure A.5 (Refer to Appendix A).The PCAIA was tested for gain in the anechoic chamber at Bradley University. The measured gain of the PCAIA was found to be 20dBi. The measured radiation characteristics of the proximity coupled (PC) patch antenna are summarized in Table A.1 (Refer to Appendix A).

CHAPTER 3

MICROSTRIP PATCH ANTENNA THEORY

3.1 Introduction

The microstrip antenna is now an established kind of antenna that is confidently prescribed by designers worldwide [8]. The micro strip antenna concept finally became very popular in the 1970s when aerospace applications, such as spacecraft and missiles, produced the impetus for researches to investigate the utility of conformal antenna design [8].A large number of commercial needs are met by the use of micro strip and printed antenna. There are many applications for printed antenna technology such as The Global Positioning System (GPS). GPS applications such as the asset tracking of vehicles as well as marine use have created a large demand for antennas. Satellite Digital Audio Radio Services (SDARS) have become an alternative to AM and FM commercial broadcast in automobiles [8]. Another example is Wireless Local Area Network (WLAN) provide short range high-speed data connections between mobile devices (such as a laptop computer) and wireless access points. The range for wireless data links is typically around 100 to 300 feet indoors and 2000 feet outdoors [8].

Basically, a micro strip patch antenna consists of a radiating patch on one side of a dielectric substrate which has a ground plane on the other side as shown in Figure 3.1 [5]. Generally this patch is made of conducting material such as copper or gold and follows any possible shape [5]. The radiating patch and the feed lines are usually photo etched on the dielectric substrate.

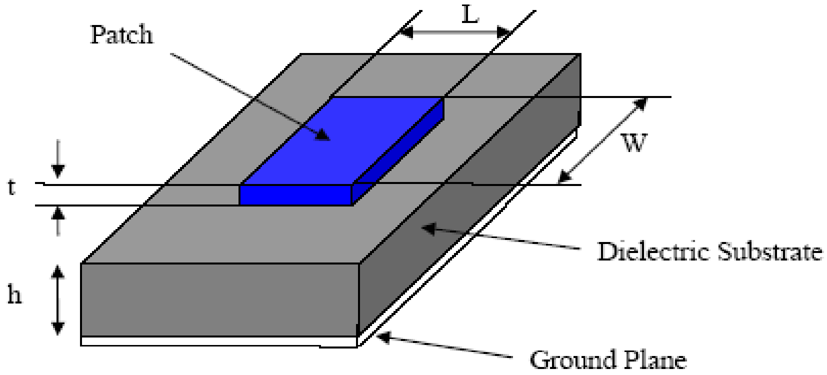
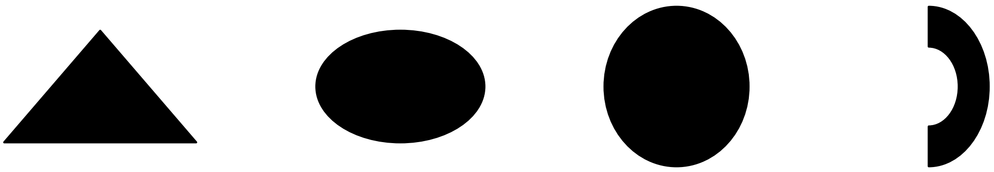


Figure 3.1: Structure of a microstrip patch antenna [5]

To make prediction and analysis become easier, the patch is commonly square, rectangular, circular, triangular, elliptical or some other common shape as shown in Figure 3.2. For a rectangular patch, the length L of the patch is usually $0\ 3333\ \lambda_o < L < 0.5\ \lambda_o$, where λ_o is the free-space wavelength [5]. Usually the patch is selected to be very thin such that $t << \lambda_o$ (where t is the patch thickness).The height h of the dielectric substrate is usually $0.003\ \lambda_o << h << 0.05\ \lambda_o$ [5].The dielectric constant of the substrate is typically in the range $2.2 \leq \varepsilon_r \leq 12$ [18].

The ones that are most desirable for antenna performance are thick substrates whose dielectric constant is in the lower end of the range because they provide better efficiency, larger bandwidth, loosely bound fields for radiation into space, but at the expense of large element size [9]. The higher dielectric constants for thin substrates are desirable for microwave circuitry because they require tightly bound fields to minimize undesired radiation and coupling, and lead to smaller element sizes [9]. However, because of their greater losses, they are less efficient and have relatively smaller bandwidth [8]. A compromise has to be reached between good antenna performance and circuit design because micro strip antennas are often integrated with other microwave circuitry [8].

(a) Square (b) Rectangular (c) Dipole (d) Circular



(e) Triangular (f) Elliptical (g) Circular ring (h) Ring sector

Figure 3.2: Common shapes of micro strip patch elements [23]

The most popular micro strip patch is rectangular patch antenna because of ease of analysis and fabrication, and their attractive radiation characteristics, especially low cross-polarization radiation. These antennas can be mounted on the surface of high-performance aircraft, satellites, Bluetooth, missiles, cars and even handheld mobile telephone [8].

3.2 Advantages And Disadvantages Of Micro strip Antennas [5]

The main advantages of micro strip patch antennas are light weight and low volume, low profile planar configuration which can be easily made conformal to host surface, low fabrication cost, hence can be manufactured in large quantities. Besides that it's also supports both, linear as well as circular polarization. Other advantages are it can be easily integrated with microwave integrated circuits (MICs), capable of dual and triple frequency operations and mechanically robust when mounted on rigid surfaces. Microstrip patch antennas suffer from a number of disadvantages as compared to conventional antennas. Some of their major disadvantages are narrow bandwidth, low efficiency, low gain, extraneous radiation from feeds and junctions, poor end fire radiator except tapered slot antennas, low power handling capacity and surface wave excitation.

Microstrip patch antennas have a very high antenna quality factor (Q). Q represents the losses associated with the antenna and a large Q leads to narrow bandwidth and low efficiency. Q can be reduced by increasing the thickness of the dielectric substrate. But as the thickness increases, an increasing fraction of the total power delivered by the source goes into a surface wave. This surface wave contribution can be counted as an unwanted power loss since it is ultimately scattered at the dielectric bends and causes degradation of the antenna characteristics.

3.3 Feeding Methods

Micro strip patch antennas can be fed by variety of method [5]. These methods can be classified into two categories that contacting and non-contacting. Basically in the contacting method, the RF power is fed directly to the radiating patch using a connecting element such as a micro strip line. In the non-contacting scheme, electromagnetic field coupling is done to transfer power between the micro strip line and the radiating patch [5]

There are many methods to feed the microstrip. Among the most popular feed technique used are the micro strip line, coaxial probe (both contacting schemes), aperture coupling and proximity coupling (both non-contacting schemes).

3.3.1 Microstrip Line Feed [5]

This feed technique, a conducting strip is connected directly to the edge of the micro strip patch as shown in Figure 3.3. The conducting strip is smaller in width as compared to the patch .The advantage of this type feed arrangement is the feed can be etched on the same substrate to provide a planar structure.

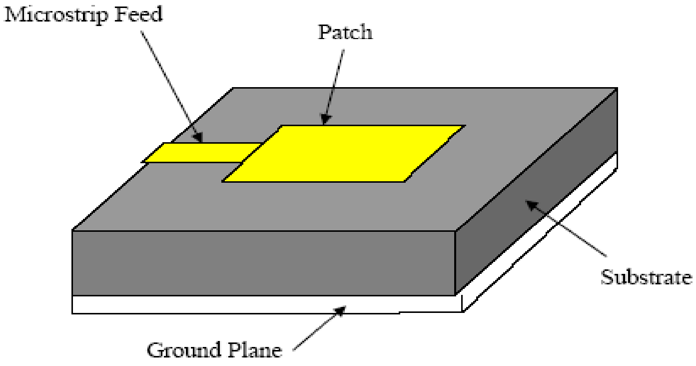


Figure 3.3: Microstrip line feed [5]

The main purpose of the inset cut in the patch is to match the impedance of the feed line to the patch without any additional matching element. This can be achieved by properly determining and controlling the inset position. Therefore this feeding scheme becomes easier. This feed method is easy to fabricate and simple to determine impedance matching as well. However as the thickness of the dielectric substrate being used, increases, surface waves and spurious feed radiation also increases, which hampers the bandwidth of the antenna .The feed radiation also leads to undesired cross polarized radiation.

3.3.2 Coaxial Feed [5]

The coaxial feed or probe feed is a very common technique used for feeding micro strip patch antennas. Based on Figure 3.4, can be seen the inner conductor of the coaxial connector extends through the dielectric and is soldered to the radiating patch, while the outer conductor is connected to the ground plane.

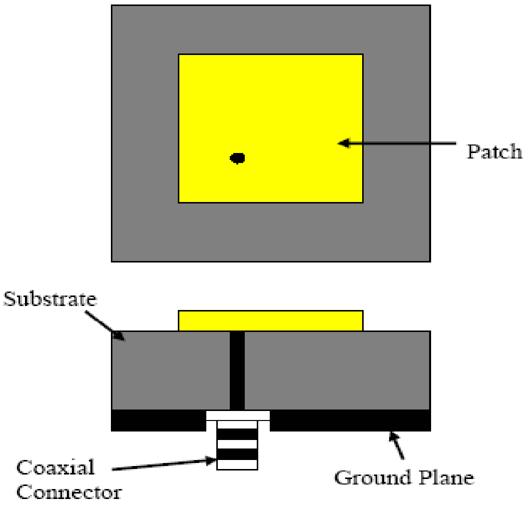


Figure 3.4: Probe Fed Rectangular Microsrtip Patch Antenna [5]

The main advantage of this feeding scheme is that the feed can be located at any desired location inside the patch in order to match with its input impedance. This feed method is easy to fabricate and also has low spurious radiation. However, its major disadvantage is that it provides narrow bandwidth and quite difficult to model since a hole has to be drilled in the substrate and the connector protrudes outside the ground plane. Therefore does not make it completely planar for thick substrates ($h > 0.02\ \lambda_o$). Then for thicker substrates, the increased probe length makes the input impedance more inductive, leading to matching problems. It is seen above that for a thick dielectric substrate, which provides broad bandwidth, the micro strip line feed and the coaxial feed suffer from numerous disadvantages.

3.3.3 Aperture Coupled Feed [5]

This feed technique, the radiating patch and the microstrip feed line are separated by the ground plane as shown in Figure 3.5. Coupling between the patch and the feed line is made through a slot or an aperture in the ground plane.

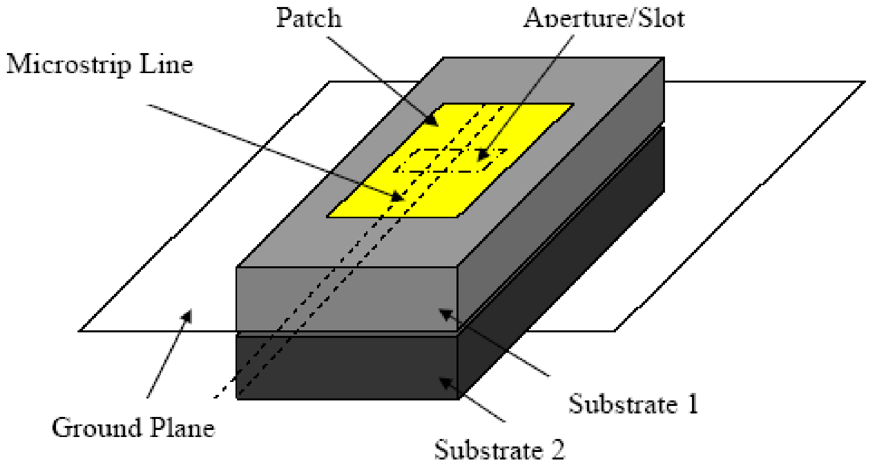


Figure 3.5: Aperture- coupled feed [5]

The coupling aperture is usually centered under the patch, leading to lower cross polarization due to symmetry of the configuration. The amount of coupling from the feed line to the patch is determined by the shape, size and location of the aperture. Since the ground plane separates the patch and the feed line, spurious radiation is minimized. Generally, a high dielectric material is used for the bottom substrate and a thick. On the other hand, a low dielectric constant material is used for the top substrate to optimize radiation from the patch .The major disadvantage of this feed technique is that it is difficult to fabricate due to multiple layers, which also increases the antenna thickness. This feeding scheme also provides narrow bandwidth.

3.3.4 Proximity Coupled Feed [5]

This type of feed technique is also called as the electromagnetic coupling scheme. Based on Figure 3.6, two dielectric substrates are used that the feed line is between the two substrates and the radiating patch is on top of the upper substrate. The main advantage of this feed technique is that it eliminates spurious feed radiation and provides very high bandwidth (as high as 13%), due to overall increase in the thickness of the microstrip patch antenna. This scheme also provides choices between two different dielectric media, one for the patch and one for the feed line to optimize the individual performances.

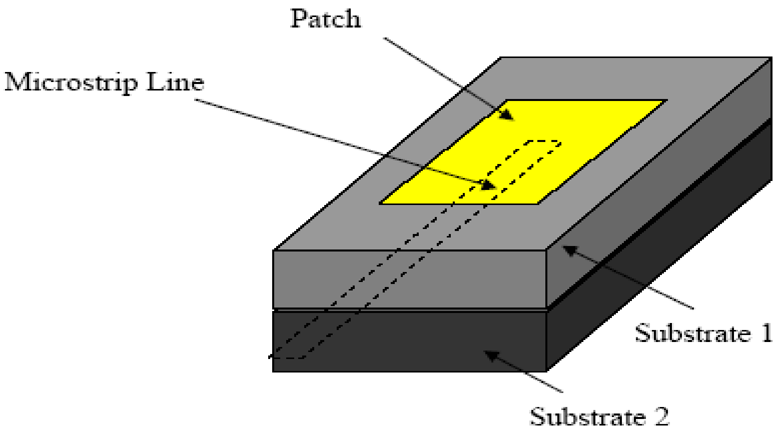


Figure 3.6: Proximity –coupled Feed [5]

Matching can be achieved by controlling the length of the feed line and the width-to-line ratio of the patch. The major disadvantage of this feed scheme is that it is difficult to fabricate because of the two dielectric layers which need proper alignment. Also, there is an increase in the overall thickness of the antenna.

Table 3.1 Below summarizes the characteristics of the different feed techniques [5]

Characteristics	**Microstrip Line Feed**	**Coaxial Feed**	**Aperture Coupled Feed**	**Proximity Coupled Feed**
Spurious feed radiation	More	More	Less	Minimum
Reliability	Better	Poor due to soldering	Good	Good
Ease of Fabrication	Easy	Soldering and Drilling needed	Alignment needed	Alignment required
Impedance Matching	Easy	Easy	Easy	Easy
Bandwidth (achieved with impedance matching	2 – 5%	2 – 5 %	2-5 %	3%

3.4 Methods of Analysis [18]

The most popular models for the analysis of microstrip patch antennas are the transmission-line model, cavity model, and full wave model. The transmission line model is the simplest of all and it gives good physical insight but it is less accurate. The cavity model is more accurate and gives good physical insight but is complex in nature. The full wave models are extremely accurate, versatile and can treat single elements, finite and infinite arrays, stacked elements, arbitrary shaped elements and coupling. These give less insight as compared to the two models mentioned above and are far more complex in nature. For this purpose only transmission line model will be considered.

3.4.1 Transmission-Line Model [5]

This model represents the microstrip antenna by two slots of width *W* and height *h*, separated by a transmission line of length L. The microstrip is essentially a non-homogeneous line of two dielectrics, typically the substrate and air. Hence, as seen from Figure 3.8, most of the electric field lines reside in the substrate and parts of some lines in air. As a result, this transmission line cannot support pure transverse electric magnetic (TEM) mode of transmission, since the phase velocities would be different in the air and the substrate. Instead, the dominant mode of propagation would be the quasi-TEM mode. Hence, an effective dielectric constant (ε_{reff}) must be obtained in order to account for the fringing and the wave propagation in the line. The value of ε_{reff} is slightly less then ε_r because the fringing fields around the periphery of the patch are not confined in the dielectric substrate but are also spread in the air as shown in Figure 3.8

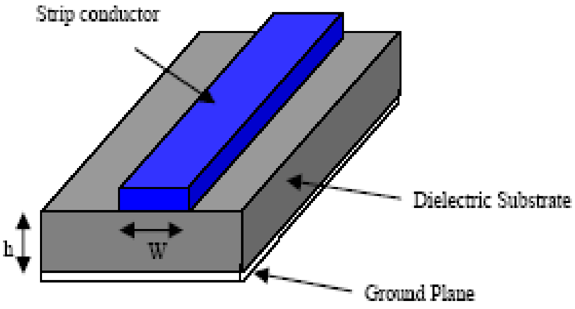


Figure 3.7: Microstrip Line [5]

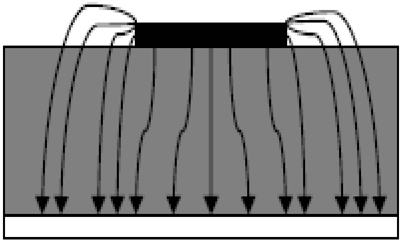


Figure 3.8: Electric Field Lines [5]

3.5 Conclusions

Microstrip patch antennas are very useful especially in wireless communication. It can be applied in the field of military devices, spacecraft, and radar communication and so on. Besides that microstrip patch antennas need a low cost, light weight and easy to fabricate. The main important parts that should be known are the basic characteristic of microstrip patch antenna, feeding methods and analysis method in order for designing the patch antenna.This project will apply one of the techniques in designing Active Integrated Antenna. The technique that been applied is transmission line model and for feeding method, the microstrip line feed is used.