MICROSTRIP ARRAY ANTENNA FOR AUTOMOBILE RADAR SYSTEM

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A thesis dissertation submitted in partial fulfillment of the
requirements for the award of the degree of
Master of Electrical-Telecommunications Engineering

Faculty of Electrical Engineering

Universiti Teknologi Malaysia

MAY, 2006

To my dear beautiful mother,
my dear decent father,
my beloved husband
and my lovely daughter:

Thank you for your continuous Encouragement
and deepest Support.
You are always my Inspiration to do Better.

ACKNOWLEDGEMENT

First of all, thanks to our creator, “Allah” for the continuous blessing and for giving me the strength and chances in completing this project.

Special thanks to my project supervisor, Dr.Nor Hisham Bin Haji Khamis, for his guidance and encouragement during this master project. I greatly appreciate his care and dedication in constructively criticizing my work, including my thesis.

I would like to convey my deepest appreciation to the postgraduate students Eng.Tellaha and my friend Siti Zurida Ibrahim, who have helped me by sparing some times to share ideas that have nurtured my thoughts in the area of the project.

Gratitude is also extended to faculty of Electrical Engineering, Universiti Teknologi Malaysia for the full support in this project.

I am profoundly grateful for my family especially my parents, who always love me, believe in me, and support me, no matter where I am.

Finally, I wish to express my appreciation and thanks to my husband, Mohd. Kabashi, whose unconditional support and caring is an indispensable source of my strength.

ABSTRACT

Point to point communication brings a crucial responsibility to antennas since they are expected to provide a transmission between those devices. The Industry, Scientific and Medical (ISM) Band, Unlicensed with the range 2.4 - 2.4835 GHz is used as the operation band. In a high performance point to point application where size, weight, cost, performance, ease of installation are constrains, a suitable antenna is very much required. To meet these requirements, microstrip antenna is usually preferred. Microstrip antennas are currently one of the fastest growing segments in the telecommunications industry and promised to become the preferred medium of telecommunication in the future. Although microstrip antenna has several advantages, it also has several drawbacks such as low gain and narrow bandwidth. These disadvantages can be overcome by constructing many patch antennas in array configuration. This project focuses on the design of microstrip patch antenna with operating frequency at 2.45GHz for automobile radar system. The antenna is mainly intended to be used as receiving antenna and receives signals transmitted from an automobile radar system in order to control the movement of the car. An array design based on series fed configuration and consisting of four rectangular patch elements was designed, simulated, fabricated and measured. These elements are connected directly to the microstrip line at their corners and inclined 45 degree in order to achieve circular polarization. The simulation, fabrication and measurement methods were accomplished with the aid of MathCAD, AWR Microwave Office 2004, AutoCAD, FR4 Board, UV Equipment, Macroni Scalar Analyzer 6204 and Anechoic Chamber. The design met the ISM BAND Standard and able to operate in this Band. The fabricated array is found to have a variation in the operating frequency from the simulation resonant frequency. Return loss results of the fabricatd design have a value of -32.8dB with a bandwidth of 4.8%, which could be considered as a narrow band width. This further strengthens the theory of series feed configurations that arrays produce better return loss but narrower bandwidth than that of a single element.

ABSTRAK

Komunikasi titik ke titik membawa tanggungjawab yang genting kepada antena di mana ia diharapkan boleh menyediakan penghantaran antara peranti penghantar dan peranti penerima. Jalur Industri, Saintifik dan Perubatan (ISM), yang tidak berlesen dengan had antara 2.4 - 2.4835 GHz digunakan sebagai jalur operasi. Dalam perlaksanaan titik ke titik berprestasi tinggi yang mana saiz, berat, kos, prestasi dan pemasangan yang mudah menjadi kekangan, antena yang sesuai adalah sangat diperlukan. Untuk memenuhi keperluan ini, antena mikrojalur biasanya dipilih. Antena mikrojalur masa kini merupakan salah satu segmen yang berkembang pesat dalam industri telekomunikasi dan menjanjikan medium yang dipilih pada masa akan datang. Walaupun antena mikrojalur mempunyai beberapa kelebihan, ia juga mempunyai beberapa kelemahan seperti gandaan yang rendah dan lebar jalur yang sempit. Kelemahan ini boleh diatasi dengan menggabungkan banyak antena tampalan dalam konfigurasi array. Projek ini memfokus kepada merekabentuk antena mikrojalur tampalan dengan frekuensi operasi pada 2.45GHz untuk sistem radar automobil. Antena ini pada pokoknya digunakan sebagai antena penerima dan menerima isyarat yang dihantar dari sistem radar automobil supaya pergerakan kereta dapat dikawal. Array yang direkabentuk berdasarkan kepada konfigurasi suapan sesiri dan terdiri daripada empat element tampalan berbentuk segi empat bujur telah direka, disimulasi, dihasilkan dan diukur. Elemen-elemen ini telah disambungkan di pepenjuru secara terus ke garisan mikrojalur dengan 45 darjah bengkok untuk mencapai polarisasi bulat. Kaedah simulasi, pembuatan dan ukuran telah disempurnakan dengan bantuan MathCAD, AWR Microwave Office 2004, AutoCAD,Papan FR4,Peralatan UV, Macroni Scalar Analyzer 6204 dan Anechoic Chamber. Rekaan telah mencapai piawaian jalur ISM dan berupaya beroperasi pada jalur ini. Array yang telah dihasilkan diperhatikan mempunyai variasi pada frekuensi operasi berbanding dengan frekuensi gema yang disimulasi. Kehilangan balikan yang diperolahi pada rekaan yang dihasilkan adalah sebanyak -32.8dB dan mempunyai lebar jalur yang sempit sebanyak 4.8%. Ini menguatkan lagi teori berkenaan konfigurasi suapan sesiri di mana array boleh menghasilkan kehilangan balikan yang lebih baik tetapi mempunyai lebar jalur sempit berbanding satu elemen.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

SYMBOL	DISCRIPTION
E	Electric Field Intensity
f	Frequency
G	Gain
H	Magnetic field
I	Current
J	Current Density
K	Wave number
U	Radiation Intensity
U_{max}	Maximum radiation intensity
Z_0	Characteristic impedance
Z_L	Load impedance
Z_{in}	Input impedance
C	Coupling
D	Directivity
h	Substrate heigt
c	Velocity of light in free space
Ψ	Progressive phase
λ	wavelength
λ_g	Guided wavelength
β	Phase constant
ε_r	Dielectric constant
ε_{eff}	Effective dielectric constant
Φ	Azimuth angle
θ	Elevation angle
η	Efficiency
Γ	Reflection coefficient
μ	Permeability
μ_r	Relative Permeability

LIST OF ABBREVIATIONS

ABBREVIATION	DISCRIPTION
RF	Radio Frequency
ISM	Industrial, Scientific and Medical
PCB	Printed Circuit Board
EM	Electromagnetic
UV	Ultra Violet
VSWR	Voltage Standing Wave Ratio
HPBW	Half Power BeamWidth
AF	Array factor

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Background of the problem

This thesis proposes the development of microstrip rectangular patch antennas in array configuration that can be implemented for point-to-point microwave link. In the first chapter, the background of this project has discussed, providing the objective and scope of this work in addition to the application of automobile radar antenna and the antenna position.

Communication can be broadly defined as the transfer of information from one point to another. A communication system is usually required when the information is to be conveyed over a distance. The transfer of information within the communication system had commonly achieved by superimposing or modulating the information into an electromagnetic wave, which acts as a carrier for the information signal. At the required destination, the modulated carrier was then received and the original information signal can be recovered by demodulation. Over the years, sophisticated techniques have been developed for this process using electromagnetic carrier waves operating at radio frequencies as well as microwave and millimeter wave frequencies. [1]

At frequencies below 3 GHz, many different types of antennas are used such as simple monopole, dipoles, patches or arrays. Dish antennas are generally practical and commonly used at microwave frequencies (above approximately 3 GHz). In wireless data applications, satellite communications and other high bandwidth microwave applications. [1]

Point to point communication brings a crucial responsibility to antennas since they are expected to provide the wireless transmission between those devices, beside being able to indicate good signal to noise ratio and immunity to noise, the antennas in microwave links will have portray compact structures and ease of construction to be mounted on various devices. [2]

In high performance pint to point application where size, weight, cost, performance and ease of installation are very much required. To meet these requirements, microstrip antennas are preferred; they are currently one of the fastest growing segments in the telecommunications industry and promise to become the preferred medium of telecommunications in the future. Since early days, there has been tremendous worldwide activity aimed to develop an efficient antenna. [1]

Although microstrip antenna has several advantages like low profile, light weight and simple to manufacture, it also has several disadvantages like low gain, narrow bandwidth with associated efficiency is low. These disadvantages can; however be overcome with intelligent designs incorporated in whole antenna structures. One of the ways to overcome these problems is by constructing many patch antennas in array configuration. [1]

For this project, microstrip patch array antenna was designed, simulated, and fabricated for point-to-point communication. Results between simulation and fabrication were analyzed and compared.

1.2 Applications of automobile systems

Millimeter wave radars are used as forward looking sensors in order to detect and discriminate cars and obstacles on the road far ahead. On the other hand, it is also used for measurement of speed over ground, road surface condition sensing (rain, ice), detection of near-by ear and side obstacles, as well as detection of road boundaries and early warning of side crash impact. Many types of automobile radar system applications will be discussed as follows: [3]

1.2.1 Autonomous Vehicles Application

The car radar has a possible use in autonomous vehicles, where the range fills the gap between the "navigation" sensors (as GPS) and the short-range "parking" sensors. Possible applications include vehicles running in fairly standardized paths, as mining trucks, cleaning vehicles and also some agricultural vehicles. [3]

1.2.2 Surveillance From A Fixed Spot Application

Another application of these methods is to detect for example cars breaking down in sensitive road areas, as bridges, where a stopped car would rapidly lead to traffic congestion. [3]

Tracking of moving targets, i.e. of objects in the dynamic picture, can be used for example as surveillance of traffic flow. The radar can determine the instantaneous average speed in different lanes, warn for congestion and for traffic stops, and control traffic signals. [3]

Also, target tracking makes it possible to log the number of vehicles passing an area defined by "tripwires" and give accurate information on these vehicles (passing time, velocity, which way they leave the surveyed area etc.). [3]

1.2.3 Military Applications

The car radar in itself is short-range surveillance radar, useful for short range border surveillance and for guard (sentinel) duties, also in total darkness to use the same radar sensor as a driving aid and as an aid to guard and surveillance duties. When the vehicle is parked, the car radar is switched to "guard mode", and the vehicle guards itself! The car radar can be the soldier's "Personal Radar". [3]

1.2.4 A Safety Application

Obstacles on the track, and people deliberately or inadvertently intruding on the rail area, are great safety problems for the subway and other urban rail public transport an intrusion alarm able to detect people is required. [3]

1.3 Range

Over the years but in most cases the basic intention has been to provide measurement of range, velocity and angle of targets on the highway to enable longitudinal control of the radar equipped vehicle to be undertaken. To achieve this the radar has to operate in an environment ranging from scorching heat to snowstorms, be small and lightweight, and be capable of mass production with consistent performance at low cost These are severe constraints for a radar system [3].

Road surface sensing is performed at close range and thus allows wide beam, simple and small antennas. A variant in between is required for side and forward looking (imaging) radar allowing crash prediction with range requirements on the order of a few meters; however, while sensors with simple and small antennas may suffice here, the angular discrimination of near-by objects requires a distribution of sensors with many wavelengths spacing.[3]

Vehicle radar can be used for anti – collision and cruise control purposes to measure the relative speed and distance between adjacent vehicles in the same lane, a range of up to 200 meters is required. [3]

1.4 Antenna Position

To date, two basic positions have been used for the placement of the sensor. Each of these has its merits and demerits. [3]

1.4.1 Front Bumper Area

The front bumper area is an apposition which may include the front grille. This position provides many advantages and disadvantages as discussed below:

- **Advantages:**

  This position is a physically vulnerable position

- **Disadvantages:**

- It may be subject to impact during an accident or even during parking. Even if no operational damage is sustained any impact damage may cause misalignment of the sensor.
- The low mounting height exacerbates the multi-path problem and the sensor aperture is likely to be contaminated by road dirt that will require mechanical cleaning.
- Being external it is to be expected that in winter the aperture can become covered with ice that may severely degrade the sensor performance.
- Heating the aperture to overcome this problem may not be that simple since conductive wires buried in the aperture may affect the radar beam.
- If the license plate is considered for use as a Radom then the legislative requirements of some countries may preclude this use if metallization of the plate is required.
- The space available in the front bumper/grille area may be inadequate for housing the sensor.[3]

1.4.2 Windscreen Area

The position considered here is - the area generally occupied by the rear view mirror. This has a number of advantages, and disadvantages.

- **Advantages:**

- The sensor is inside the vehicle in a position that is mechanically cleaned by the windscreen wipers.
- It is also not as vulnerable to the effects of weather or accident damage.

- **Disadvantages:**

  - The effect of the removal of backscatter from the wiper which should have to be considered.
  - The effect of heating elements in the windscreen has also been questioned.
  - Loss measurements at 76 GHz on a heated windscreen have shown an average loss due to attenuation and scattering of 9 dB, with a variation of 1.6 dB as the windscreen was rotated through 90°. This will induce a significant reduction in radar performance.
  - The space available in the area of the rear view mirror is severely limited and will constrain the size and type of antenna structure.
  - With direct solar radiation through the windscreen this area of the vehicle may reach very high temperatures in hot climates.
  - Depending on the design of the front of the vehicle this mounting position may well induce blind ranges, at close range, due to the bonnet of the vehicle screening the radar beam.
  - It is probable that by raising the sensor up to the maximum height possible in the vehicle, so that the effects of multi-path will be reduced. [3]

1.5 Antenna Size

The size of the antenna is a direct function of the radar operating frequency, the higher the frequency the smaller the antenna for the same beam width. At 10 GHz the formation of a 3" wide beam requires an antenna with an aperture of approximately 600". At 77 GHz a 3" wide beam requires an antenna with an aperture of only 80 mm, so that, the antenna is a cost critical component of an automotive radar sensor. [3]

1.6 Objective Of The Project

The aim of this project is to design, simulate, and fabricate a microstrip patch array antenna operating in ISM Band at 2.45 GHz, pint to point communication for automotive radar system.

1.7 Scope of The Project

The project is divided into few phases as follows:

- Understanding the fundamentals of microstrip rectangular patch antenna
- Design a Microstrip rectangular patch array antenna.
- Simulate the Microstrip rectangular patch array antenna using microwave office 2004, v 6.51.
- Fabricate the design.
- Analyze and compare between fabrication and simulation results**.**

1.8 Methodology Of The Project

To carry out this project, the following methodology is designed:

- Generating the model, starting with a rectangular patch and then complete the whole antenna array model
- Simulating the derived model.
- Fabrication.

- Testing and verification.

The following figure is a block diagram of the project methodology which describes the methods will be used in implementing this project.

1.9 Organization of Thesis

The layout of this thesis has organized in five chapters. The first chapter is an introduction, which provides information regarding the project background, objectives, scope of the project and layout of the thesis.

The literature review that discussed in the second chapter will presents the application and a background to the project that includes a microstrip antenna overview, single rectangular patch antenna design followed by rectangular patch array antenna design, basic antenna theory in addition to the array antenna theory and its properties.

The third chapter shows the methodology of the thesis besides explaining the software needed for the project and the methods that employed. Design and simulation results has shown by presenting all the design specifications and results obtained from MathCAD calculation followed by simulation results using AWR MICROWAVE OFFICE 2004, v.6.51, and subsequent analysis that discussed.

Fabrication method, results, and analysis of fabrication and comparison between simulation and fabrication results were explained in chapter 4, which are Design Fabrication and Measurement Results.

The last chapter is a Conclusion and Future Work. This chapter will conclude the findings of the project and provide recommendations for future work.