INTEGRATED LENS ANTENNA (ILA) FOR AUTOMOTIVE APPLICATION AT FREQUENCY 77GHZ

FATEIN AMINA BT ABD MALIK

This report is submitted in partial fulfilment of the requirements for the award of Bachelor of Electronics Engineering (Telecommunication Electronics) with honours

Faculty of Electronic and Computer Engineering
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AZMAN B AWANG
Pensyarah
Fakulti Kej Elektronik dan Kej Komputer (FKEKK),
Universiti Teknikal Malaysia Melaka (UTeM),
Karung Berkunci 1200,
Ayer Keroh, 75450 Melaka

Alamat Tetap: NO. 52 FELDA TITI,

71 600 K.KLAWANG, JELEBU,

NEGERI SEMBILAN.

Tarikh: 09 MAY 2008

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Signature	:	....
Supervisor's Name	:	Encik Azman Bin Awang Teh
Date	:	09 May 2008

For my beloved parent and siblings

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ABSTRACT

The purpose of this project is to analyze an Integrated Lens Antenna (ILA) for automotive radar application at 77 GHz. Lens Antenna is an attractive and competitive technology that gave a good performance and have low cost. It can be applied in the related fields like lane departure warning or pre-crash application. Different types of lens have difference dielectric constant that will give difference result in their distribution energy and surface wave. The objective of this project is to accommodate of analyzed a Lens Antenna with good distribution energy and reducing an excitation of surface wave. Beside that, the shape of the lens also will influence the result. A convenience method to eliminate substrate modes with integrated antennas is to place the antenna on a dielectric lens. The antennas placed on dielectric lens (homogenous dielectric feed) tend to radiate most of their power into the lens side. The shapes can be analyzed using Geometrical Optic (GO) Method and MathLab which is suitable.

ABSTRAK

Projek ini dilaksanakan bertujuan untuk menganalisa bentuk Lens Antenna Bersepadu (ILA) iaitu teknologi yang menarik dan berdaya saing yang mempunyai keboleharapan yang tinggi serta harga yang rendah untuk diaplikasikan dalam radar kenderaan pada 77GHz. Ia boleh digunakan didalam bidang yang berkaitan seperti amaran penyimpangan dan pengera pelangaran. Lens yang berlainan mempunyai dielectric constant yang berlainan akan memberikan keputusan berlainan didalam penyebaran tenaga dan gelombang permukaannya. Objektif projek ini adalah menganalisa bentuk Lens Antenna yang mempunyai penyebaran tenaga yang baik dan mengurangkan gelombang permukaan. Disamping itu, bentuk lens juga turut mempengaruhi keputusan tersebut. Cara yang mudah untuk meghapuskan modes substrate antenna bersepadu adalah dengan meletakkan antenna pada dielectric lens. Antenna yang dilettakan pada dielectric yang sama akan cenderung untuk menyinar keseluruhan tenaganya. Ianya akan dianalisa mengunakan kaedah Geometrical Optic (GO) dan MathLab mengikut kesesuaian.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYBOLS/ABBREVIATION

ACC	- Automotive Cruise Control
CAR	- Collision Avoidance Radar
CPW	- Coplanar Waveguide
FDTD	- Finite Different Time Domain
GA	- Genetic Algorithm
GO	- Geometrical optic
GO & PO	- Geometrical Optic And Physical Optic
ILA	- Integrated Lens Antenna
PO	- Physical Optic

CHAPTER 1

INTRODUCTION

1.1 Introduction Of Project

Today Integrated Lens Antenna (ILA) is involved in many applications where it is competitive and attractive technology. This project will be concentrate on analyzing the most suitable shape of ILA that can be applied in Automotive Cruise Control (ACC) radar at 77 GHz. Beside that, the effect of dielectric constant of lens ξ_r, the length and radius to the distribution energy of lens antenna should be familiarized to analyzing the shapes. This shape of integrated lens antenna can be applied in related field like lane departure warning or pre-crash application since the current industrial effort at 77GHz range are focused on automotive radar. The problem that will be considered is to have good distribution energy, reduce the surface wave and low cost material.

1.2 Objectives Of Project

The Integrated Lens Antenna type has several advantages where it having moderate size, weight and in addition has variety of sources make it a competitive and attractive technology. At this time, it has been used in many applications including in automotive radar application at 77GHz. Lens antenna is interesting to analyze because it can provide the best directivity which is very important in radar application. The main objectives of this project can be state as:

1. To study an Integrated Lens Antenna (ILA) in automotive radar application at 77GHz.

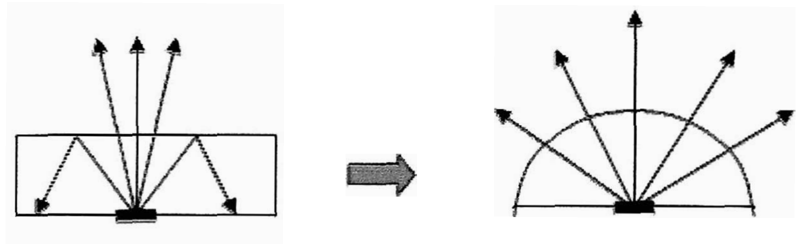
2. To accommodate with lens antenna shape in order to get the most suitable shape with good distribution energy and low cost material.

Nowadays, a few type of lens antenna shape have been introduced, but which is the most suitable shape that can be used in automotive cruise control radar such as lane departure warning or pre-crash application still in conversation. This project will be analyzing all factors that should taking into account. At the end of this project, the proper shape of lens antenna should be finding by considering the minimum material cost however still having a good directivity and can be trusted.

1.3 Problem Statement

This project will consider improving and solving these problems:

- Performance of distribution energy due to trapped surface wave.



a) b) The trapped surface wave is eliminated

Figure 1.1: Trapped Surface Wave.

- The use of Luneburg Lens that require graded dielectric lens, which is expensive to manufacture [1].

- The presence of undesirable interface and air gap [1].

1.4 Scope of Project

The scope of the project can basically be split into these:

- Analyzes an Integrated Lens Antenna at frequency of 77GHz and the effect of lens's dielectric constant.

- Since to provide low cost material and reducing an excitation of surface wave with good distribution energy, it will depend on the primary feed and shape of the lens where phase distribution on a surface is different for lenses with different radius.

- The software that can be used to achieve optimal simulation results at desired resonance is Math Lab.

1.5 Methodology

The methodology can be explained briefly as below:

This project is to analyze about lens shape that can be apply in automotive radar application, so method that will be used is collect related data from books, technical paper and anything that will give an information. These will be used as references to get the best results hopefully in determine the suitable shape of lens antenna for automotive radar application. Before move to literature review stage it is very important to get information that connected. From the literature review, lens antenna shapes and suitable fed are analyze. Integrated Lens Antenna which have advantages in low cost but still having good distribution energy and can be trusted will be analyzed. These are including lens shape, the length, width, radius of lens and the right type material. The material type that will give the best results is preferred. It will analyze using geometrical optic approach. Finally, desired integrated lens antenna should be found.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview

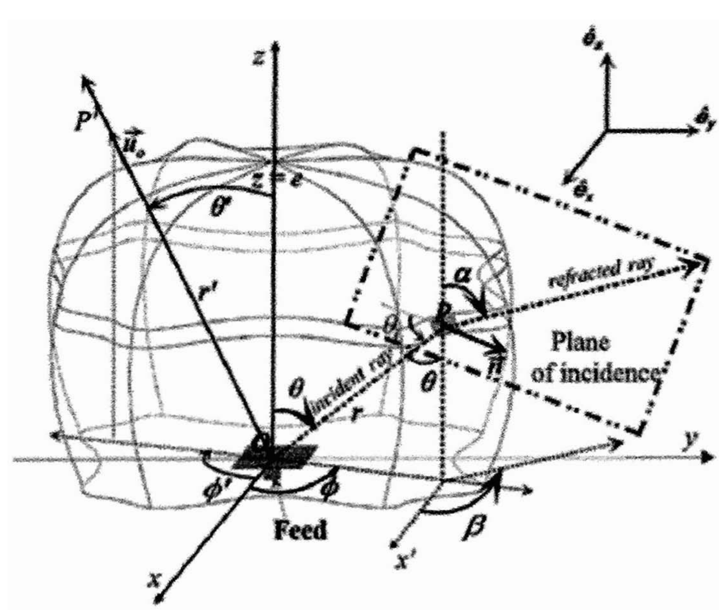
This project is to analyze Integrated Lens Antenna (ILA) shape for Automotive Cruise Control (ACC) radar application. According to that, firstly is to find shapes of Integrated Lens Antenna that have been introduced. Several shapes that have been study here are arbitrary, Luneberg lens, two shell spherical lenses, single spherical lens and extended hemispherical lens shapes used in millimeter-wave. The use of millimeter-wave spectrum (26-140 GHZ) has been experience an improvement of recent as many system such as collision avoidance radar and wireless communication link [11].Through the background study, these lens shape have their advantages and disadvantages applied in millimeter-wave frequency band.

Automotive radar systems offer the capability to measure simultaneously range, relative speed and azimuth angle of all observed objects inside the observation area [2]. So, far mainly video systems have been used to perform the object classification in specific automotive applications. These technical solutions need high computation power for image processing and therefore it is very expensive. Other than that, video system has limitations in automotive application generally due to bad weather condition.

However, all these limitations of video systems can be overcome by radar systems but radar based target system for automotive applications is common and technical challenge [2]. This project was focused in analyze lens antenna shapes that will reduce a surface wave and good distribution energy at 77GHz for automotive cruise control radar. Today Integrated Lens Antenna is involved in many applications where it is competitive and attractive technology because of low cost and their good performance.

2.2 Arbitrary Shapes

Automotive radar at 77GHz is currently being developed for automotive cruise control radar or collision avoidance application. There are several methods to achieving a wide angle system. A new synthesis method has been presented for the design of homogeneous dielectric lens antennas of arbitrary shape [3]. Figure below show the geometry of a 3-D lens antenna of arbitrary shape.



(a)

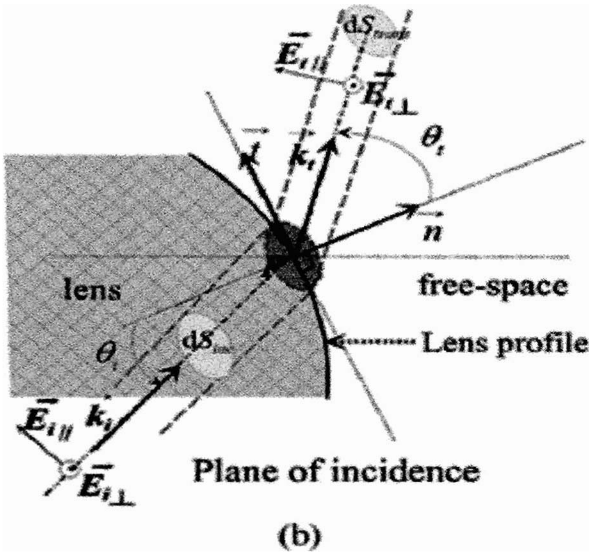


Figure 2.1: (a) Geometry of a 3-D lens antenna of arbitrary shape. (b) Vector and angular notations in the plane of incidence [3].

Figure 2.1: (a) show the general geometry of an arbitrary with homogeneous dielectric (ξ_r) 3-D lens, and (b) the associated local coordinates system and oriented angles. The base of the lens is planar and is located in the plane Z=0. It is fed by a point-source fed from the origin of the Cartesian coordinates system of unit vectors $\hat{e}_x$, $\hat{e}_y$, and $\hat{e}_z$. The unknown lens profile and the central thickness of the lens are labeled $r(\theta,\phi)$ and $e = r(\theta = 0,\phi)$, respectively. $r(\theta,\phi)$ is computed using GO so that the radiation intensity $g(\theta,\phi)$ of the primary feed coincides, after refraction at the dielectric/free-space boundary, with a desired radiation intensity $h(\alpha,\beta)$. (θ,ϕ) and (α,β) define the directions of the incident and refracted rays, respectively. P' is the observation point and P denotes any secondary source point located on the lens surface [3].

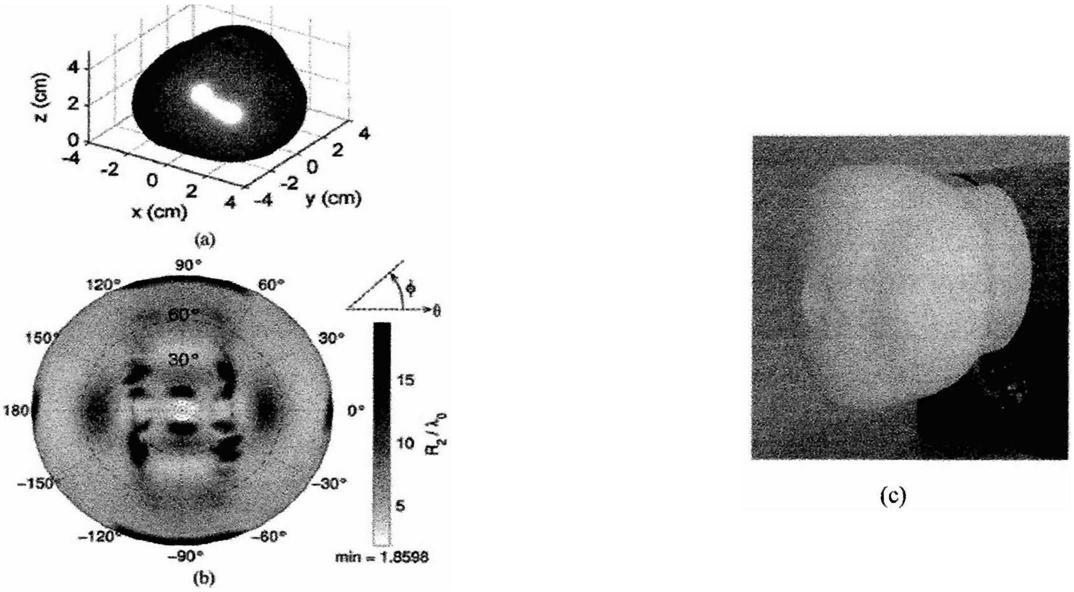


Figure 2.2: (a) 3-D shape of the synthesis lens (b) Minimal radius of curvature of the $|R_2|$ optimized lens (c) 3-D lens fabricated in Teflon ($\xi_r = 2.1$) [3].

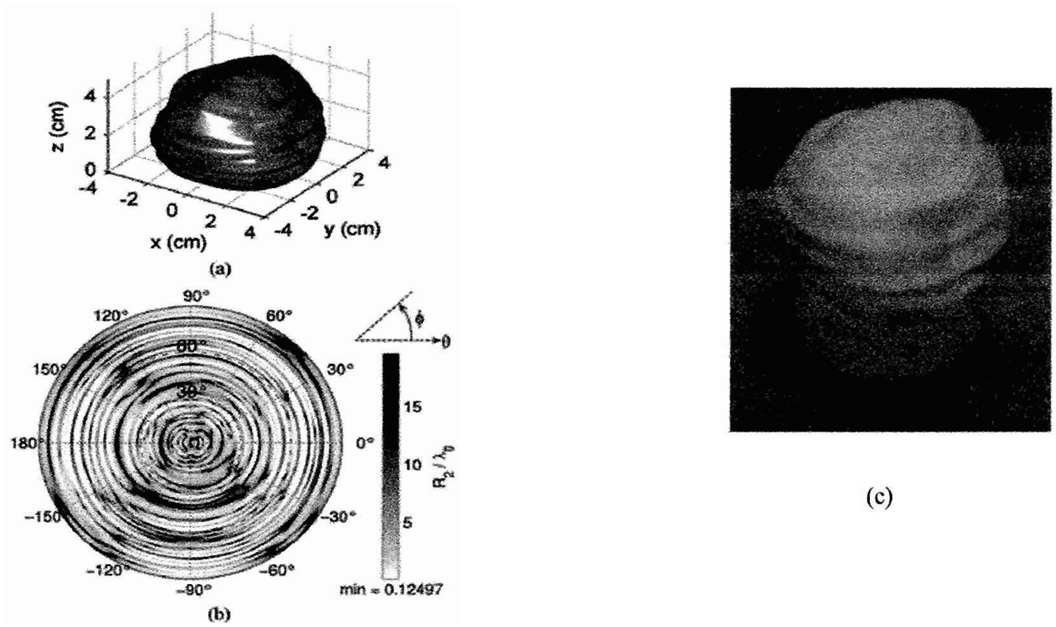


Figure 2.3: (a) 3-D shape of the optimized lens (b) Minimal radius of curvature of the $|R_2|$ optimized lens (c) Optimized 3-D lens fabricated in Teflon ($\xi_r = 2.1$) [3].

A new synthesis method has been presented for the design of homogeneous 3-D dielectric lens antennas of arbitrary shape. This lens shape is firstly defined using GO principles (power conservation and vector Snell's law). This design procedure is successfully applied at 58.5 GHz. An lens profile is defined so that refraction at the lens boundary convert the primary radiation of a microstrip 2x2 patch antenna array into an asymmetric pattern. A first prototype has been fabricated in Teflon. The comparison between the measured and computed patterns is very satisfied where the theoretical radiation performance is determined using a hybrid method combining GO and PO principles. This conventional formulation has been generalized to allow the analysis of arbitrary 3-D shape. Nevertheless, a significant inconsistency appears between the desired and measured patterns.

To minimize this inconsistency, an optimization procedure of the lens shape is carried out. It consists in a local surface optimization of the lens profile previously defined. A multidimensional conjugate-gradient method is implemented in order to reduce the distance between the desired radiation pattern and the theoretical one computed using the conventional PO diffraction integral [3]. This second step is also has been experimentally applied at 58.5 GHz. Although the optimized 3-D lens has small radius of curve, agreement is has been obtained between experimental and simulated results.

However, this new synthesis method has several limitations. In particular, the existence and unicity of a solution can not be guarantied. The stability and convergence rate of the algorithm strongly depends on the initial and boundary conditions. Furthermore, they impose a priori the radiation characteristics of the primary feed [3]. The real-time optimization of the lens profile and primary feed could improve the convergence of the algorithm and this work is currently under progress. In addition, to design electrically small lens antennas of arbitrary shape, the same methodology can be implemented.

2.3 Luneberg Lens Shapes

Another method is the use of Lunenburg lens, but this requires a graded dielectric lens, which is expensive to manufacture at high frequency.

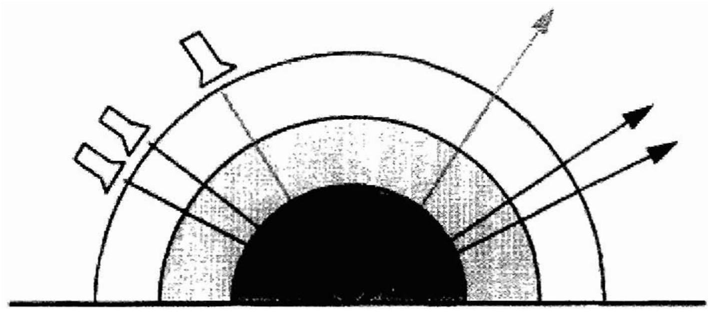


Figure 2.4: The utilization of a half-lens [4].

2.3.1 Uniform Luneburg Lens Antenna

An ideal Luneburg lens consists of a spherically symmetric dielectric sphere with continuous varying permittivity from two at the center of the inner core to the one at the outer surface. Which is $\xi_r = 2 - (r/a)^2$ where *a* is the radius of the sphere. A Luneburg lens antenna transforms the point source radiation into the plane wave and vice versa [5]. However, the Luneburg lens is constructed by a finite number of spherical shells, retaining reasonable performance in practice. Table 2.1 shows the material and thickness for a five-shell 30λ (λ in free space) diameter uniform lens. Usually feed horns or open-ended waveguides are used to illuminate the lens. In this paper, a typical horn antenna is modeled using an end-fire antenna consisting of four infinitesimal dipoles, as shown in Figure 2.5. For a Luneburg lens antenna with fixed diameter, the radiation performance is improved by increasing the number of shells, but the performance becomes saturated with $\approx 1\lambda$ thickness for each shell.