RADIAL LINE SLOT ARRAY (RLSA) ANTENNA DESIGN FOR POINT TO POINT COMMUNICATION AT 5.8 GHz

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To my beloved mother and father

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ABSTRACT

A new type of linearly polarized Radial Line Slot Array (RLSA) antenna developed by FR-4 substrate is proposed for outdoor WLAN point to point application. The WLAN is based on the IEEE 802.1 la standard and the operating frequency range is the upper UNII band (5.725-5.875) GHz. The frequency range is use for point to point microwave link. Point to point microwave link is a wireless connection between one point to another point. Before this all the research has been conducted on conventional RLSA antenna developed by polypropylene and two layers copper foil. But these antennas are quite expensive and difficult to develop. Typically the point to point system uses standard parabolic dish antenna. However the uses of these antennas have some disadvantages such as aperture blockage. To overcome this drawback, a new antenna design is proposed and investigated. Therefore, this research was conducted in order to design and develop antenna with aesthetic, low cost, high performance, durable and flat antenna that could be utilized in point to point microwave link. The development of linearly polarized radial line slot antenna (RLSA) with experimental performance is presented. The method is beam squinted design. The prototype development processes included specification definition, selection of the cavity's dielectric material and construction of prototype. The production of prototypes is divided into two stages. The first stage is to simulate the radiation pattern of slot arrangement at operating frequency. The second stage is to produce the prototype and to evaluate its performance. The prototype of RLSA has been successfully constructed and tested for outdoor WLAN point to point application

ABSTRAK

Satu rekabentuk baru linearly polarized Radial Line Slot Array (RLSA) antena telah dihasilkan menggunakan bahan FR-4 sabagai dielektrik. Antena ini telah dicadangkan untuk penggunaan di luar bangunan, bagi aplikasi LAN secara wayarles (outdoor WLAN). Aplikasi WLAN adalah berdasarkan standard IEEE 802.11a dan frekunsi operasi adalah atas UNII band (5.725-5.875) GHz. Julat frekunsi digunakan untuk gelombang micro titik-ke-titik. Gelombang micro titik-ke-titik ialah sambungan tanpa wayar dari satu titik ke titik yang lain. Banyak kajian telah dilakukan terhadap antena RLSA yang dibangunkan daripada polypropylene dan kepipis dua lapisan. Tetapi, kos pembangunanya sangat mahal dan kompleks. Kebiasaanya sistem titik ke titik menggunakan parabola dish yang standard. Namun demikian, penggunaan antena ini mempunyai sedikit kelemahan seperti aperture blockage. Untuk mengatasi kelemahan ini, satu rekabentuk antena baru di cadangkan dan dikaji. Maka, kajian ini dijalankan untuk merekabentuk dan membangunkan antena yang estetik, berkualiti, kuat, flat dan berkos rendah yang boleh di laksanakan dalam gelombang micro point to point. Pembangunan linearly polarized radial line slot antenna (RLSA) telah dijalankan dengan kajian eksperimen. Kaedah yang digunakan ialah rekabentuk beam squinted. Proses pembangunan prototaip ini termasuk spesifikasi definasi, pemilihan cavity's dielectric material dan pembinaan prototaip. Proses pembangunan prototaip ini dibahagikan kepada dua peringkat. Peringkat pertama ialah mensimulasi alunan radiasi penyusunan slot di frekunsi operasi dan peringkat kedua ialah menghasilkan prototaip dan menilai keberkesananya. Prototaip antena RLSA telah berjaya dihasilkan dan telah diuji pada aplikasi “outdoor WLAN”.

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LIST OF SYMBOLS AND ABBREVIATIONS

2D	-	Two dimension
3D	-	Three dimension
ε_{eff}	-	Effective dielectric constant
ε_o	-	dielectric constant of free space
ε_r	-	dielectric constant / permittivity
λ	-	wavelength
λ_g	-	guided wavelength
λ_o	-	free space wavelength
μ_o	-	Permeability of free space
c	-	velocity of light
D	-	directivity
dB	-	decible
f	-	Frequency
b	-	Radial Cavity Height
IL	-	Insertion Loss
L	-	Inductance
P_i	-	Incident Power
P_{max}	-	Peak handling Capacity
P_r	-	Reflected Power
P_t	-	Transmitted Power
R	-	Resistance
RL	-	Return Loss

TEM	-	Transverse Electromagnetic
V	-	Voltage
ρ_a	-	Slot Array Radius
ρ_{sc}	-	Short circuit distance
ρ_w	-	waveguide radus
L_s	-	Slot length
w_s	-	Slot width
Z_o	-	characteristics impedance

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CHAPTER 1

INTRODUCTION

A Radial Line Slot Array (RLSA) antenna is attractive for point-to-point communications as well as for receiving Direct-to-Home television programs. Geometrical simplicity, low profile feature and cost effectiveness make the Radial Line Slot Antenna (RLSA) a unique choice for outdoor wireless LAN point to point application. Generally, an RLSA antenna is an attractive candidate for high efficiency and high gain antenna for direct broadcast from satellite (DBS) application. This type of antenna belongs to the slotted waveguide arrays family, which is the only and the most promising candidates for high gain planar antennas, having the smallest conductor losses among all the planar feeding structures such as the microstrip lines [1]. It is composed of two circular parallel plate waveguide, which can supports two types of wave traveling or standing wave. Therefore, this antenna is more versatile in comparison of other antennas. Outstandingly, the RLSA can achieve more than 30dBi of gain in the 5.8 GHz band [30]. The: low cost feature of RLSA has motivated some researchers to expand its design for lower frequency applications, such as WLAN [26] and Solar Power Satellite antenna [31]. The research is to design antenna using FR-4 substrate by chemical etching process for outdoor/indoor WLAN point to point microwave link for Upper Unlicensed National Information Infrastructure (UNII) band at (5.725 - 5.875)GHz. Under the Malaysian Communications and Multimedia Commission (MCMC) regulations, the maximum ElRP over the frequency band shall not exceed 1000mW or 30dBm [29].

Typically point to point communication system uses standard parabolic disk antenna. However, the use of this type of antenna has some disadvantages. In a primary fed design, there is a considerable aperture blockage. An offset design, which eliminates the blockage, is on the other hand susceptible to physical damages as its feed is significantly exposed from the body of reflector. Furthermore, in the latter design, the alignment procedure is quite involved.

A more beneficial design is the linearly polarized Radial Line Slot Array (RLSA) type antenna. Advantages of this antenna include its high radiation efficiency, low profile due to it can be mounted at roof and wall, ease of installation, feed rear-mounted, not subject to leaf and water build-up due to its flat surface.

1.1 Objective

The Project Objective was to develop a Linearly Polarized Radial Line Slot Array (RLSA) Antenna by using photo etching process on FR-4 Substrate Operating at 5.8 GHz.

1.2 Research Background

Point to point communication can be happened via small aperture antennas with gain about 30-35dBi. Various types of appropriate antennas, including parabolic reflectors, microstrip arrays and RLSA have been proposed. Parabolic reflectors are the most widely used. However, a more compact, with low profile, robust, easy

installation and pleasing aesthetics antenna is desirable. Microstrip antennas possess the above characteristics, but they are generally expensive and poor efficiency.

A good alternative solution could be a slot antenna array. Such an array is the RLSA antenna which initially has been proposed by Ando M. [1]. Much research into RLSA antenna has been performed in Japan, with a lot of success reported for circularly polarized antennas. The RLSA antenna is expected to have a high efficiency of more than 80% for the antenna gain of 30-35 dBi. However, the design of a linearly polarized RLSA, which would be required for the reception of direct broadcast satellite TV programs, applications for microwave point-to-point and point- to-multipoint communication links in Malaysia is still not fully established. Because of this, further investigation of linearly polarized RLSA antenna is required. Based on earlier study done by Paul W. Davis [2], a procedure for the design of linearly polarized RLSA antennas have been developed. This procedure will be explained in the next sections.

1.3 Research Scope

This research works involve investigation and development of the linearly polarised RLSA antenna as an extension of the research works conducted by University of Queensland [3], [4], [5]. The design of RLSA antenna in this project is a combination of theoretical and experimental approaches. Firstly, theoretical slot surface design is developed by the slot surface design software. The resulting slot surface parameters such as slot position and orientation are fed into the theoretical radiation pattern modelling software developed using Matlab to evaluate the expected radiation pattern. After the obtained theoretical radiation pattern result is satisfied, the design software will output desired Computer Aided Manufacturing (CAM) file format in order to develop the antenna prototypes.

The original slots surface design software of RLSA is developed using Borland C++ 5.00 by University of Queensland that runs on Unix platform. This RLSA slot surface software was slightly modified to enable it run successfully in IBM compatible personal computer. In the slots surface design, some parameters in the input data file have to be changed according to the frequency, relative permittivity of dielectric material and dimension of RLSA antenna.

A coaxial-to-waveguide feeding structure has to be developed to convert the travelling radial waveguide field mode present in the RLSA antenna's radial cavity into the coaxial field mode to travel along the coaxial feed line. The construction of the feeding structure is required to match the impedance of the radial waveguide to the coaxial feeding line.

In order to evaluate the performance of RLSA antenna in receive point to point signal, two test-beds have been setup. The test-bed is utilizing the conventional RLSA antenna provided developed by polypropylene and copper foil and another one is setup by using the RLSA antenna prototypes. The performance of RLSA antenna prototypes have been compared to conventional RLSA antenna in receiving point to point signal.

1.4 Thesis Structure

This thesis is organized into six chapters to completely cover the whole research works that have been conducted for the radial line slot array antenna project.
The second chapter discusses about the literature review.
The third chapter describes about the radiating slot design and return loss improvement
Chapter four discusses about simulation and antenna prototype manufacturing
The chapter five describes about the experimental setup of the antenna.
The chapter six discuss about result analysis, discussion and future works