Faculty of Electrical and Electronic Engineering Technology

Design of a Broadband Reflectarray Antenna For X-Band Radar Application

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Bachelor of Electronics Engineering Technology (Telecommunications) with Honours

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Design of a Broadband Reflectarray Antenna For X-Band Radar Application

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A project report submitted
in partial fulfillment of the requirements for the degree of
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PROJEK SARJANA MUDA II

Tajuk Projek : Design of a broadband reflectarray for X-Band radar application

Sesi Pengajian : 2019/2020

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I declare that this project report design of a broadband reflectarray for X-Band radar application is the result of my own research except as cited in the references. The project report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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I hereby declare that I have checked this project report and in my opinion, this project report is adequate in terms of scope and quality for the award of the degree of Bachelor of Electronics Engineering Technology (Telecommunications) with Honours.

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DEDICATION

Thanks to Allah,

For give me a good health and strength while making this report.

My beloved father and mother,

Rumli Bin Kamis & Jamilah Binti Ahmad,

Who has always been our epitome of love and always pray for my strength to finish up this report.

My beloved relatives,

My siblings,

Thank you for your support and pray.

The person who has been very understanding and helpful,

DR. Muhammad Inam Abbasi

For the support and guidance. Hope that I always be remembered.

My unforgettable friends,

My housemate, my course mate and all BEET student's intake June 2019,

my struggle not yet ends.

Finally, friends that always together during this fourth years study,

Hopefully achieved what we aspired.

ABSTRACT

A unit cell antenna for the X-band is a type of antenna designed to function within the X-band frequency range, which is commonly classified as 8-12 GHz. These antennas are commonly employed in radar and communications systems, as well as other applications requiring high-frequency signal transmission and reception. Next, the patch antenna, which is made up of a flat, metallic patch suspended above a ground plane, is a typical type of X-band unit cell antenna. A microstrip transmission line often feeds the patch, allowing the antenna to be integrated into a larger system or device. Patch antennas are distinguished by their tiny size, low profile, and good performance at X-band frequencies. The slot antenna is another type of X-band unit cell antenna that is made out of a rectangular slot cut into a metallic sheet or waveguide. Besides that, the slot antenna which is often fed by a coaxial transmission line, is notable for its large bandwidth and strong gain at X-band frequencies. A unit cell antenna's performance in the X-band can be measured using a range of metrics, including gain, directivity, and efficiency. These parameters can be shown on a graph to demonstrate how the antenna operates throughout a range of frequencies or under various operating situations. However, one of the limitations of the reflectarray antenna is its narrow bandwidth that limits its use in many applications. This work provides the design characterization and analysis of reflectarray antennas for bandwidth enhancement and its use in the X-band radar applications

ABSTRAK

Antena sel unit untuk jalur-X ialah sejenis antena yang direka bentuk untuk berfungsi dalam julat frekuensi jalur-X, yang biasanya dikelaskan sebagai 8-12 GHz. Antena ini biasanya digunakan dalam sistem radar dan komunikasi, serta aplikasi lain yang memerlukan penghantaran dan penerimaan isyarat frekuensi tinggi. Seterusnya, antena tampalan, yang terdiri daripada tampalan logam rata yang digantung di atas satah tanah, ialah jenis antena sel unit jalur-X yang tipikal. Talian penghantaran jalur mikro sering menyalurkan tampalan, membolehkan antena disepadukan ke dalam sistem atau peranti yang lebih besar. Antena tampalan dibezakan oleh saiznya yang kecil, profil rendah dan prestasi yang baik pada frekuensi jalur-X. Antena slot ialah satu lagi jenis antena sel unit jalur-X yang diperbuat daripada slot segi empat tepat yang dipotong menjadi kepingan logam atau pandu gelombang. Selain itu, antena slot yang sering disalurkan oleh talian penghantaran sepaksi, terkenal dengan lebar jalur yang besar dan keuntungan yang kuat pada frekuensi jalur-X. Prestasi antena sel unit dalam jalur-X boleh diukur menggunakan julat metrik, termasuk perolehan, arahan dan kecekapan. Parameter ini boleh ditunjukkan pada graf untuk menunjukkan cara antena beroperasi sepanjang julat frekuensi atau di bawah pelbagai situasi operasi. Walau bagaimanapun, salah satu batasan antena reflectarray ialah lebar jalur sempit yang mengehadkan penggunaannya dalam banyak aplikasi. Kerja ini menyediakan pencirian reka bentuk dan analisis antena reflectarray untuk peningkatan lebar jalur dan penggunaannya dalam aplikasi radar jalur X

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INTRODUCTION

1.1 Background

Reflectarrays have been utilized in high-gain antenna designs since Hertz discovered electromagnetic wave propagation in the latter decades of the 19th century. The purpose of this project is to design a unit cell to create a broadband reflectarray antenna for X-band radar application. The advantages of reflectarray antennas, including as low profile, simplicity of production, and pattern sculpting, have piqued people's curiosity. Besides, the primary design of areflectarray is defined by an array of components arranged on a flat surface to reflect theoccurrence signals from an appropriately distant feed. Next, such as their low profile, ease of construction, and ability to shape patterns, have sparked a lot of interest.

1.2 Problem Statement

Reflectarray antenna is a recently evolved antenna that combines the advantages of the high gain parabolic reflectors and electronically beam scanning phased array antennas. Conventionally, parabolic reflectors and phased array antennas are used for high gain beam shaping and beam scanning applications. Moreover, the reflectarray has the potential to be a low cost and simple solution in many high gain antenna applications including military and civil radars. However, one of the limitations of the reflectarray antenna is its narrow bandwidth that limits its use in many applications. Therefore, this work focuses on the design characterization and analysis of reflectarray antennas for bandwidth enhancement and its use in the X-band frequency range (8GHz-12GHz) radar applications.

1.3 Project Objective

The main aim of this project is to design A Broadband Reflectarray Antenna For X-Band RadarApplication.

Specifically, the objectives of this works are to:

1. Design reflectarray unit cells within X-band frequency range (8GHz-12GHz).
2. Optimize the unit cell design to achieve wider phase range.
3. Utilize the proposed unit cell design to create a broadband reflectarray antennafor X-band radar applications.

1.4 Scope of Project

The scope of this project are as follows:

a) Unit cell design using CST software.

b) Analyze the reflection loss and reflection phase results of unit cells.

c) Fabricate unit cells and perform scattering parameter (S11) measurement.

d) Design the periodic reflectarray antenna and perform far-field analysis.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Reflect array antenna commonly known as have an array of unit cells, illuminated by feeding antenna and also it usually a horn then with the advantages, including as low profile, ease of production, and pattern shaping, reflect array antennas have generated a wide acceptance[1]. The primary architecture of a reflectarray antenna is defined by an array of elements assembled on a flat surface to reflect incident signals from an appropriately distant feed[2]. Besides, the primary design of a reflect array is defined by an array of components arranged on a flat surface to reflect the occurrence signals from an appropriately distant feed. Next, such as their low profile, ease of construction, and ability to shape patterns, have sparked a lot of interest.

Previously, rectangular unit cells were used in the design of the reflectarray antenna. The simple rectangular cells, on the other hand, have a limited range of reflection phase angles thatare less than 360 degrees. As a result, some waves may not be reflected at the proper angle, resulting in a phase mistake. The antenna's performance will suffer as a result[3]. The majorityof reflectarrays are made using a flat substrate and a microstrip reflecting element of variable length or size. However, the microstrip element's fundamental disadvantage is its limited bandwidth, which is mostly driven by the resonance phenomena. Multiple resonances have been generated utilising stacked layers in a variety of experiments to enhance the bandwidth of the reflectarray[4].

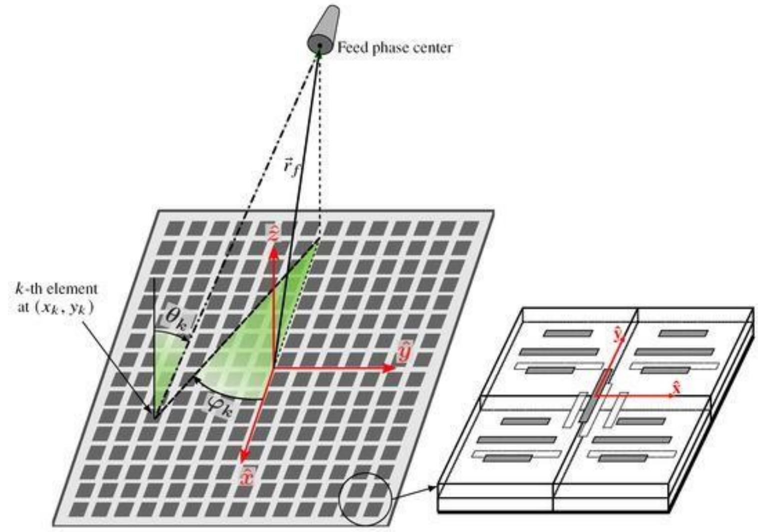
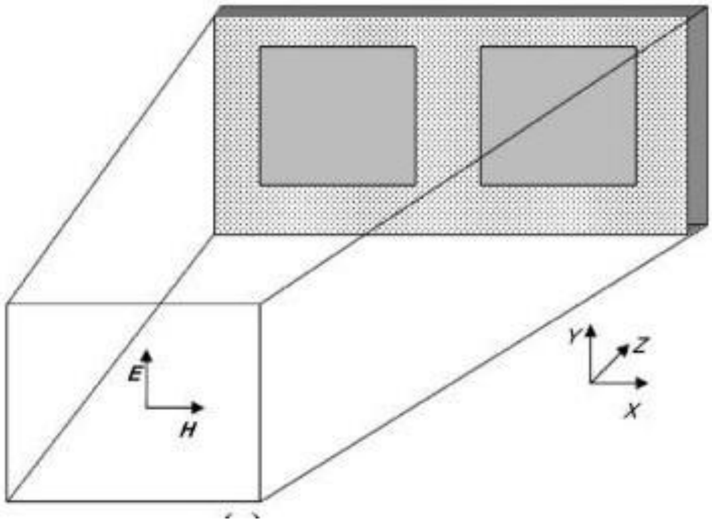


Figure 2.0.1: The unit cell and single-offset reflectarray.

Figure 2. 1: shows the unit cell and single-offset reflectarray. The reflectarray is made upof a number of reflecting unit cells and is planar. In the XZ plane, the feed phase Centre is located at $\vec{r}_f$ each reflectarray element has a different incidence angle[5].

A waveguide is a high-frequency signal feed line made of electromagnetic material. Microwave communications, aerospace, radars, telecommunications, and other high-frequency applications all make use of them. Depending on the wave frequency, waveguides can be made ofdielectric or conductive materials. Horns and reflector antennas commonly use circular waveguidefeeds, but the majority of the microwave system requires a more standard rectangular waveguide. There are several methods for transforming between a circular waveguide propagating the mode and a rectangular waveguide transmitting the mode [6].



(a)

(b)
Figure 2.2*: the structure of a waveguide*

Figure 2.2 shows depicts the structure of a waveguide simulation in which electric fields are stimulated in the Y-direction, resulting in E-walls on the upper and bottom walls of the cavity.As a result, H-walls form on the interior cavity of the waveguide simulator's left and right walls. (b) In the waveguide aperture, there is a reflectarray patch element[7].

2.2 Unit cell

A unit cell element with minimal loss is the best choice for efficient reflectarray antenna performance. However, the loss and phase range performance of the reflectarray unit cell elementmust be balanced. The choice of a unit cell is the initial step in the construction of a reflectarray. Both a waveguide and then a microstrip resonator can be used to make the unit. cell. Waveguide cells did not discover use in the centimeter’s wavelength region due to their large size the optimumchoice for efficient reflectarray antenna performance is a unit cell element with low loss. However,there is a compromise between the reflectarray unit cell element's loss and phase range performance.[8] Reflection response (magnitude and phase) and polarization purity are the most important unit cell features. To achieve perfect reflection, internal losses in a unit cell should be reduced to ensure that the magnitude of the reflected field is nearly equal to that of the incident field. [9]. The unit-cell is made up of microstrip lines connected to a circular microstrip patch. A circular ring is also constructed around the central structure to achieve additional resonance and minimize unit-cell size. [10]

(a)

(b)