Faculty of Electrical and Electronic Engineering Technology

DESIGN AND ANALYSIS OF METALLIC WAVEGUIDE FOR X-BAND RADAR REFLECTOR

NURATIKAH BINTI MOHD RADZALI

Bachelor of Electronics Engineering Technology with Honours

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A project report submitted
in partial fulfillment of the requirements for the degree of
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I declare that this project report entitled Design and Analysis of metallic waveguide for x-band radar reflector 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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DEDICATION

Bismillahiromanirohim

To my beloved mother,Hjh Junainah binti Ripot, and father, Hj Mohd Radzali bin Hj Mamek,thank you for all your support. It very encouraging me to keep walking the path that I made. Even though we are not always being together but your 'doa' always with me. Thank you for being there with me, thank you for being born, thank you for giving your level best in taking care of me and my stubborn (in a lovely way) siblings. Next, to my lovely siblings, thank you for always being annoying and lovely. That really help me a lot in overcome my own fear in facing a problem while doing this project. As a first born, I will always pave the way of everything in this world. Nothing can stop me in my own journey, my own story or my own fate. I will live my life to the fullest and with no regret. I will try my level best in becoming a good daughter, sister and most important is a good Muslim.

ABSTRACT

In this era of globalization, there are varous technologies that are increasingly sophisticated and many that furthur facilitate communication between people. With this improvement in communication, there are various breakdowns thaht have been done in communication. Among them is communication for civilians and also for the military. Communication that establish for the population is where, the communication done by the telecommunication company launch a telco which allows the residents to communicate with each other. In the context of military, in order to maintaiin the national security, various technologies are used to avoid enemy attacks. Communication in the military necessarily prioritizies classified information. Next, telecommunications is so important for both parties. Thus there is the X-Band frequency which is reserved for communication between the people and used in the military with a frequency range of 8GHz to 12GHz. The objective of this paper is to design a waveguide in the range of X-Band frequency to be used in measuring the results of Scattering Parameters for reflectarray cell unit. Next, to optimize the sze of the waveguide and unit cells measurements in reducing the cost of fabrication and materials used in designing the waveguideguide and unit cells reflectarray. In addtion, analysis was performed on both design objects in various types of materials in order to find and discover ways to reduce the design cost and size of waveguide shape. In this case, the process for designing a waveguide for a reflectarray is to design a unit of cells and waveguide in the X-Band frequency range. Next, optimize the waveguide size to find out the differences in the use of different materials. Fabrication is done for unit cells and waveguide to see the Scaterring Parameters results using Vector Network Analysis, then observe the differences based on simunlations and measurement results made. As a results, it can be seen from Scattering Parameters in dB will be around 10GHz. This paper shhows the processing that takes place in designing a waveguide in the X-Band frequency range 8GHz-12GHz.

ABSTRAK

Pada era globalisasi ini, terdapat pelbagai teknologi yang semakin canggih dan banyak yang lebih memudahkan perhubungan antara manusia di dunia ini. Di dalam peningkatan dalam komunikasi, terdapat pelbagai pecahan yang telah dilakukan dalam komunikasi. Antaranya adalah komunikasi bagi civillian dan juga bagi pihak kententeraan. komunikasi untuk penduduk adalah dimana, perhubungan yang dilakukan oleh syarikat telekomunikasi mengeleuarkan telco yang yang membolehkan para penduduk berhubung antara satu sama lain. Dalam konteks kententaraan pula, demi menjaga keselamatan negara, pelbagai teknologi digunakan untuk mnegelak dari serangan musuh. Komunikasi dalam kenteteraan semestinya kesulitan maklumat diutamakan. Seterusnya, telecomunikasi begitu penting untuk kedua-dua belah pihak. Dengan itu wujudla, frekuansi *X-band* ynag dimana dikhaskan untuk komunikasi diantara penduudk dan digunakan dalam kententeraan dengan julat frekuansi 8GHz sehingga 12GHz. Objektif kertas ini adalah untuk mereka bentuk *waveguide* dalam julat frekuansi *X-Band* untuk digunakan dalma mengukur hasil keputusan *Scattering Parameters* bagi *unit cell reflectarray*. Seterusnya, untuk mngoptimasikan saiz ukuran *waveguide* dan *unit cells* dalam mengurakan kos pembutan dan material yang digunakan dalam mereka bentuk *waveguide* dan *unit cells reflectarray*. Selain itu, analisis dilakukan keatas kedua-dua objek rekaan dalam pelbagai jenis material demi mencari dan menemui cara mengurangkan kos rekaan dan saiz bentuk *waveguide* tersebut. Dalam kerstas ini, process yang dilalui unutk mereka satu *waveguide* untuk *reflectarray* adalah dengan mereka bentuk *unit cells* dan *waveguide* dalam julat frekuansi *X-Band*. Seterusnya, mengoptimasikan saiz *waveguide* untuk mengetahui perbezaan pengunaan material yang berbeza. Fabrikasi dilakukan bagi *unit cells* dan *waveguide* untuk melihat hasil keputusan *Scaterring Parameters* mengunakan *Network Network Analysis*, seterusnya membuta perbezaan berdasarkan simulasi dan hasil ukuran yang dibuat. Hasil yang boleh dilihat, *Scatering Parametrs* dalam dB akan berada di sekitar 10GHZ. Kertas ini menunjukan pemprosesan yang berlaku dalam mereka bentuk *waveguide* dalam julat frekuansi *X-Band* iaitu 8GHz-12GHz.

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CHAPTER 1

INTRODUCTION

1.1 Background

X-band frequency is a microwave radio of the electromagnetic spectrum within (8GHz-12GHz). This usually using for the military and civil radar application. These radar use reflector antennas which have evolved from the big, huge parabolic reflector. Electromagnetic radiation with frequencies be are referred as radio frequencies (RF). Radio frequencies is divided into groups that have similar characteristics, called bands. X-Band is one of the bands with the range of 8GHz-12GHz. These frequencies are among those referred to as microwaves because the wavelength is short on the order of centimeters.

1.2 Problem Statement

X-band frequency range is usually for the military and civil radar application. Usually, these radars use the reflector antennas which have evolved from the huge parabolic reflector to the recently proposed planar reflector. The waveguide is also providing a crucial role in performance characterization and optimization of such reflector antennas. The design optimization and analysis of metallic waveguides for these x-band radar reflector antennas. A slight design of fabrication error can cause an adverse effect on the performance of the antenna as the radar.

1.3 Project Objective

The main aim of this project is to propose a design optimization and analysis of metallic waveguides for the x-band radar reflector antennas. Specifically, the objectives are as follows:

a) Design an x-band waveguides to be used for scattering parameter (S-Parameter) measurement of reflect array unit cells.

b) To optimize the size of the waveguide in order to save the cost and material.

c) To investigate the possibility of using different materials in order to optimize the waveguide parameters.

1.4 Scope of Project

To avoid any uncertainty of this project due to some limitations and constraints, the scope of the project is defined as follows:

a) To design a unit cell of reflectarray and waveguide using CST Studio Suite.

b) To analyze the reflection loss and the reflection phase through the unit cells results from CST Studio Suite.

c) To fabricate the unit cells and perform Scattering Parameters measurements

d) To fabricate the waveguide and perform Scattering Parameters measurements.

1.5 Expected Outcome

Based on this paper, using CST Studio Suite in designing a unit cell of reflect array and the rectangular waveguide in the range frequency of X-Band. The analysis on the reflection loss and reflection phase needed through the unit cells results in CST Studio Suite for analyzing the if any problem may occur while designing the unit cells of reflect array and rectangular waveguide. The fabrication will take place after the finalization in analysis on the unit cells and waveguide. The result from Scattering Parameters will be perform.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Antennas are particularly important requirement in establish a communication line. In establish a different application like satellite communication system, point to point microwave links and radar application needed a high gain antenna. Reflector antennas, lens antennas or antennas array can all provide high gain.[1] The advantages of reflector and array antennas were combined and known as reflectarray antennas and it more convenient for some application rather than a bulky parabolic reflector antenna[2][3]. Does not required any complex feeding network is the main advantage for reflectarray antenna [1]. The feed usually illuminates a planar reflecting surface with locally controlled the surface impedance to produced fixed or reconfigurable radiation pattern[2]. Planar reflectarrays show a promising potential in various communication applications due to their advantage of easy fabrication, low cost, and capability of beamforming [4]. However, reflectarrays suffer a drawback of narrow gain bandwidth. For planar reflectarrays with a small or medium aperture, the narrowband behaviour of microstrip radiating units is the primary factor which limits the bandwidth of the whole array [4].

2.2 X-band Radar

Radar systems are widely utilised in a variety of applications, including military applications such as identifying enemy weapon, as well as civilian applications such as automotive radar, often known as navigation in cars.[5]. Radar reflectors are widely employed in radar, navigation, and control systems as navigation signs, markers, and buoys in controlling the movement of water or air transport. The number of reflectors in the Radar Cross Section (RCS) is critical, as is the width of the scattering pattern.[6]

Table 2.1 Radar Frequency Band and Characteristics [7]

Frequency band	Frequency range	Wavelength	Characteristics and uses
L	1-2GHz	30-15cm	Large antenna &long-range surveillance
S	2-4GHz	15-7.5cm	Weather & medium antenna
C	4-8GHz	7.5-3.8cm	Small antenna & precise measurement
X	8-12GHz	3.8-2.5cm	Missile guidance, mapping, airborne
Ku	12-18GHz	2.5-1.7cm	High resolution mapping, satellite
K	18-27GHz	1.7-1.1cm	Little use
Ka	27-40GHz	1.1-0.75cm	Short range airport, survilliance
MM	40-100+GHz	0.75-0.01cm	Space to space radar

Figure 2.1 X-Band frequency usage in Angkatan Tentera Malaysia (ATM) at Pusat Komunikasi Satelit Angkatan Tentera Malaysia (PKS ATM), Kem Paya Jaras

Figure 2 1 DSS-43 70-meter X-Band spacecraft communication antenna at Canberra Deep Space Communication Complex, Australia

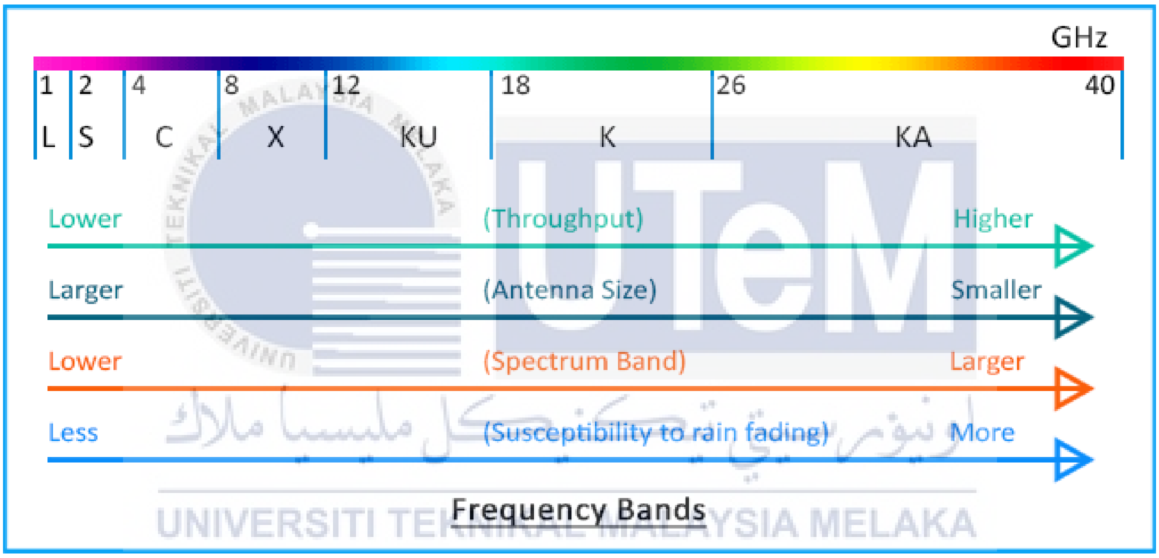

Figure 2 2: Frequency of Bands

2.3 Waveguide

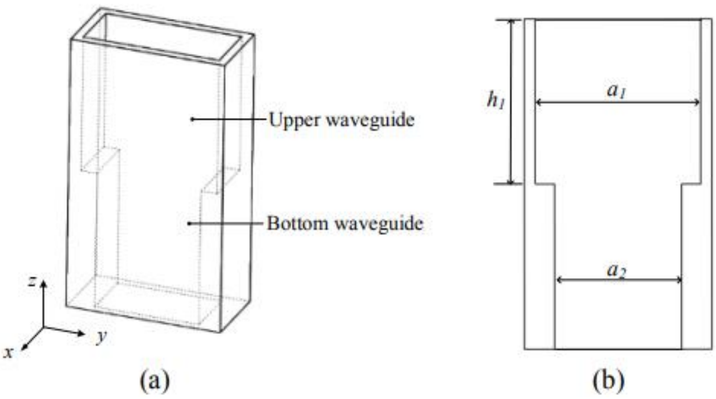

figure 2 3:(a)3-D perspective view and (b) side view of the waveguide element[3]

Figure 2.5 : Rectangular waveguide

Figure 3 shows the reflectarray of the waveguide element used in this study, which is made up of two open-ended metal rectangular waveguides. They have different y-direction widths of a1 = 3mm and a2 = 2.3mm, resulting in differing TE10 mode cut-off frequencies of f1 and f2 for the upper and lower waveguides, respectively. As a result, the waveguide element will display distinct reflection responses at different frequencies when illuminated by x-polarized incident plane waves along the –z-direction[8]. It's a rectangular, circular, or elliptical metal pipe made from materials with high electrical conductivity (copper and brass, partially plated with silver or gold or covered with a thin layer of carbon fiber). It functions to guide electromagnetic or sound waves by keeping them confined to a particular dimension over a certain distance. The propagation happen by reflecting from the internal walls of the hollow pipe. It is also a type of a metallic reflectarray where the array of a waveguides is used to reflect the incident signals. Varying the depth of waveguide can be determined by reflecting the signals phase reflection. An array of reflecting waveguides was proposed as first ever reflectarray.[9]

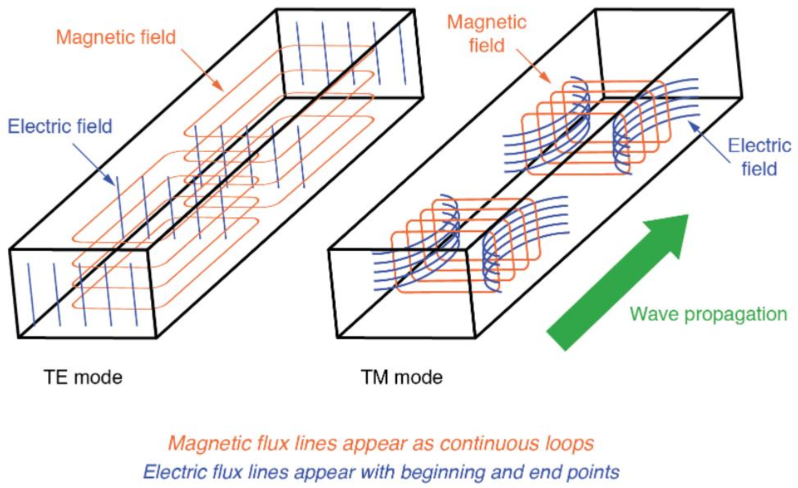

figure 2.7 : Magnetic and Electric flux line appear in TE and TM mode.

Table 2.2 Standard Rectangular Waveguide Data

Band	Recommended frequency range (GHz)	TE_{10} cutoff frequency (GHz)	EIA designation WR-XX	Inside dimension [inches (cm)]	Outside deminsions [inches(cm)]
L	1.12-1.70	0.908	WR-650	6.500 × 3.250 (16.51× 8.255)	6.660 × 3.410 (16.916× 8.661)
R	1.70-2.60	1.372	WR-430	4.300 × 2.150 (10.922× 5.461)	4.460 × 2.310 (11.328× 5.867)
S	2.60-3.95	2.078	WR-284	2.840 × 1.340 (7.214 × 3.404)	3.000 × 1.500 (7.620× 3.810)
H(G)	3.95-5.85	3.152	WR-187	1.872 × 0.872 (4.755 × 2.215)	2.000 × 1.000 (5.080× 2.540)
C(J)	5.85-8.20	4.301	WR-137	1.372 × 0.622 (3.485× 1.580)	1.500 × 0.750 (3.810× 1.905)
W(H)	7.05-1.0	5.259	WR-112	1.122 × 0.497 (0.900 × 0.400)	1.250 × 0.625 (3.175× 1.587)
X	8.20-12.4	6.557	WR-90	0.900 × 0.400 (2.286 × 1.016)	1.000 × 0.500 (2.5401× 1.270)
Ku(P)	12.4-18.0	9.486	WR-62	0.622 × 0.311 (1.580× 0.790)	0.702 × 0.391 (1.783× 0.993)
K	18.0-26.5	14.047	WR-42	0.420 × 0.170 (1.07 × 0.43)	0.500 × 0.250 (1.27 × 0.635)
Ka(R)	26.5-40.0	21.081	WR-28	0.280 × 0.140 (0.711 × 0.356)	0.360 × 0.220 (0.914 × 0.559)
Q	33.0-50.5	26.342	WR-22	0.224 × 0.112 (0.57 × 0.28)	0.304 × 0.192 (0.772× 0.448)

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2.3.1.1 This is just a sample of a very long subtopic level 3 title which consists of two or more lines

2.4 Horn Antenna

One of antenna that known as microwave antenna is horn antenna. The simplest form of antenna that deigned in under microwave. This antenna were widely used in this communication world that also involve a satellite. This frequency of microwave commonly used as X-Band frequency. 400MHz to 40GHz is the frequency range that operate stably. The shape of this antenna is like a horn and it consists of flaring metal that can direct the radio wave in beam. This antenna capable of openly radiating.

figure 2 8:Standard Gain Horn Antenna

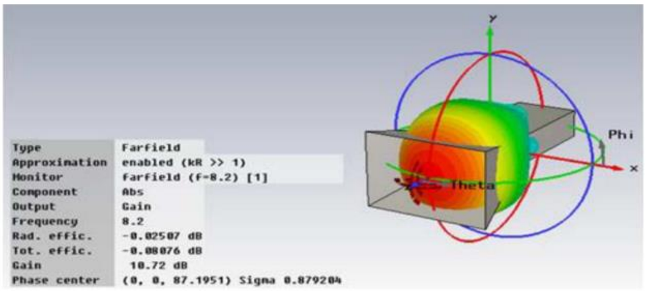

figure 2 9: Simulated horn antenna at 8.2Ghz[10]

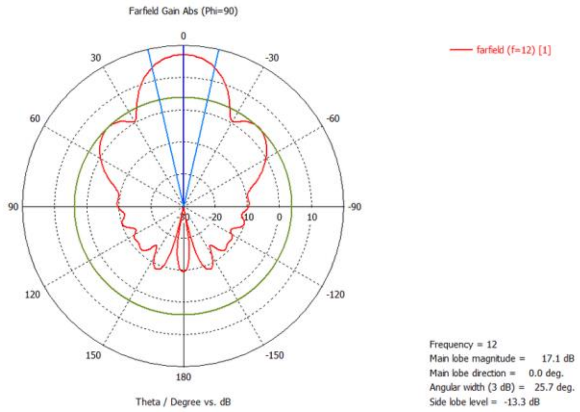

figure 2.10: Radiation Pattern for Horn Antenna

2.5 Reflectarray

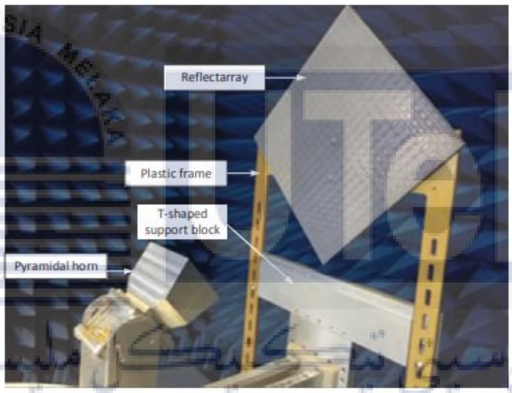

figure 2 .11:Setup of Reflectarray and Pyramidal horn

The reflectarray antenna is a hybrid of reflector and phased array antennas. Microstrip reflectarray antennas have a low profile, minimal mass, and low cost[10]. The phase curve of the reflectarray antenna should be as smooth as practical and parallel at adjacent frequencies to maintain optimal bandwidth [10]. A conventional microstrip reflectarray consist of a printed array (e.g. patch antennas), which is illuminated by a feed antenna. At its operation frequencies, a reflectarray antenna can be substitute the traditional parabolic reflector with a lightweight planar by modifying the geometry of the radiating element.