BOWTIE ANTENNA FOR GROUND PENETRATING RADAR

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ABSTRACT

There are millions of abandoned landmines, useless and dangerous, still buried in many post-war areas. The conventional technique for landmines detection is the electromagnetic induction (EMI) sensors or metal detector. Ground Penetrating Radar (GPR) has to be used to detect these targets based on the change of dielectric permittivity rather than the metal content of the targets, thus is a viable technology for landmine detection. The antenna of a GPR plays a key role in radiating impulses into the ground with a minimal degree of distortion and loss. This thesis focuses on the design of such antenna based on bowtie configuration. The design starts with the conventional bowtie which was simulated using electromagnetic simulation software, SONNET. Investigations were carried out on the antenna with right offset feed locations, different ground plane sizes and different substrate layer thicknesses. The optimum feed location was found to be at 36 mm offset. The antenna exhibits dual resonances with narrow reflection bandwidth of 9 MHz or ~1.6 %. The 3 dB half-power beamwidth was broad, which is almost 90°. Larger ground plane improved the return loss of the antenna at the input, while broadening the reflection bandwidth. Similarly, increasing the thickness of the substrate layer was found to improve the reflection bandwidth, albeit worsened the return loss. However, the return losses were still good as the values were below the -10 dB limit.

ABSTRAK

Berjuta-juta periuk api, tidak berguna tetapi masih berbahaya, terbiar dan masih tertanam di kebanyakan kawasan yang pernah mengalami peperangan. Teknik pengesanan periuk api yang lazim dipraktikkan ialah pengesan elektromagnetik (EMI) atau lebih dikenali sebagai pengesan logam. Pegesan logam adalah tidak lagi efektif untuk mengesan periuk api terkini yang mengandungi sedikit atau tiada kandungan logam. Dengan itu, Radar Penembus Bumi (GPR) mesti digunakan untuk mengesan sasaran-sasaran tersebut berdasarkan kepada perubahan pada pemalar dielektrik, dan bukan kandungan logam sasaran. Antena pada GPR memainkan peranan utama dalam pemancaran impuls ke dalam bumi dengan kesan pengherotan dan kehilangan yang minimal. Tesis ini memfokus kepada rekabentuk antena sedemikian, berasaskan konfigurasi *bowtie*. Rekabentuk dimulai dengan konfigurasi konventional yang disimulasi menggunakan perisian simulasi elektromagnet, SONNET. Kajian dijalankan terhadap berlainan lokasi suapan ofset kanan, berbeza saiz satah bumi, dan berbeza ketebalan lapisan substratum. Didapati bahawa lokasi suapan optimum adalah pada ofset 36 mm. Antena mempunyai cirian dwi resonans dengan lebarjalur balikan yang sempit bernilai 9 MHz atau ~1.6 %. Lebaralur setengah kuasa adalah luas, iaitu hampir 90°. Saiz satah bumi yang lebih besar dapat memperbaiki kehilangan kembali antena di masukan, di samping meluaskan lebarjalur balikan. Begitu juga, ketebalan lapisan substratum telah perbaiki lebarjalur balikan, tetapi memburukkan kehilangan kembali. Walau bagaimanapun, nilai ini masih baik kerana jauh di bawah paras -10 dB.

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LIST OF SYMBOLS

$\%$	:	Percentage
E_0	:	electric field constant
k	:	propagation constant
a	:	attenuation constant
b	:	phase constant
$e_{r(g)}$	:	relative permittivity
$m_{r(g)}$	:	relative permeability
m_0	:	permeability of free space
l	:	wavelength
u_g	:	velocity of the electromagnetic signal in the ground.
c	:	speed of light
Γ	:	reflection coefficient
a_e	:	effective side length
t	:	Substrate thickness
f_o	:	resonant frequency
S_{11}	:	Reflection coefficient

LIST OF ABBREVIATIONS

GPR	:	Ground Penetrating Radar
MBPA	:	Microstrip Bowtie Patch Antenna
AP	:	Anti-personnel mine
AT	:	Anti-tank mine
RDX	:	Cyclotrimethylenetrinitramine
TNT	:	Trinitro-toluene
R&D	:	research and development
EMI	:	electromagnetic induction
GMR	:	Giant Magneto-resistive sensor
FAR	:	False Alarms Rate
RF	:	radio frequency
GHz	:	Giga Hertz
MHz	:	Mega Hertz
dB	:	Decibel
VSWR	:	Voltage Standing Wave Ratio
PCB	:	printed circuit broad
CAD	:	computer-aided drawing
MoM	:	Method of Moments

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CHAPTER 1

INTRODUCTION

1.1 Objective of Project

The objective of this project is to design a Ground Penetration Radar, GPR, antenna for mine detection application. The desired specifications are frequency of operation at 0.55 GHz, standing wave ratio of at least 2, better than -10 dB return loss, 10 % bandwidth and 60° half power beamwidth radiation.

1.2 Problem Statement

Landmines have been used in war zones throughout the world, and have significant effects on civilian populations. It has a very long life-span, rendering many post-war areas both useless and dangerous. Such minefields can be found anywhere including agricultural fields, river banks, urban areas, transport routes and surrounding villages. The effect is a demoralised local population. In many post-war zones, landmines with little or no metal content have been found. They are often

quite small; made using a plastic casing and very few, if any, metal parts. Consequently, conventional metal detectors are not effective countermeasures for these mines. Metal detectors also suffer from a high false alarm rate due to other subsurface inhomogeneities especially small pieces of metal and debris lodged beneath the surface. Therefore, it is essential to have alternative detectors such as Ground Penetrating Radar (GPR) which does not rely on metal detection.

GRP works by detecting discontinuities in the dielectric properties of the soil. The size and shape of targets made from materials such as plastic can potentially be determined using this technology. However, environmental conditions such as soil type and moisture content can heavily influence the performance of a GPR system. Therefore, new or modified antenna configurations are desirable to develop robust detection schemes which can compensate for changes in background conditions.

1.3 Project Background

The study proposes a probe fed planar bowtie antenna configuration based on the design by K.W.Loi, S.Uysal and M.S.Leong of National University of Singapore [2]. Microstrip bowtie antenna is chosen because of its simple design, broadband impedance and radiation characteristics. It is also compact in size and can easily be fabricated using cost effective, readily available material.

1.4 Scopes of Project

The project scopes are as follows:

- Literature review of GRP antenna, mine clearance, microstrip antennas and feeding methods.
- Design microstrip bowtie patch antenna, MBP antenna. An example of a 3D view is shown in Figure 1.1.
- Simulation of the designed antenna with optimum feed location using SONNET electromagnetic software.
- Analyse the performance of the designed antenna.

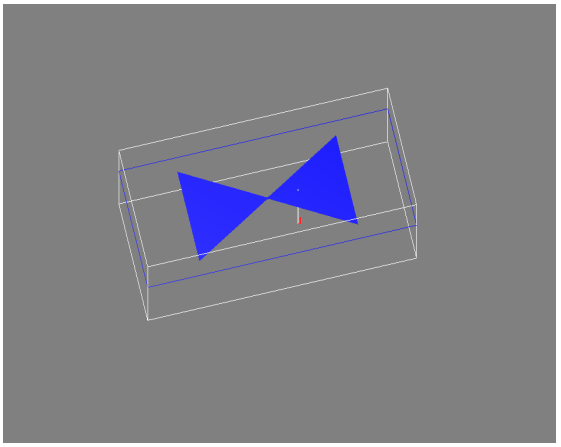

Figure 1.1 : 3D view of a probe fed MBP antenna

1.5 Thesis Organization

Chapter 1 presents the project objective, problem statement, scopes and thesis organization. In Chapter 2, mine characteristics and mine detection which consist of metal detector and GPR are presented. Chapter 3 presents brief description of antenna fundamentals and review of GPR antennas. The methodology for designing a MBP antenna suitable for mine detection application is then presented. The designed antenna was simulated and the results are given and discussed in Chapter 4. Further investigations with different ground plane sizes and substrate layer

thicknesses were performed and the results were analyzed. Chapter 5 concludes the thesis and recommendations for future work were given.

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