CHAPTER 1
INTRODUCTION

1.1 Background

Traditionally, assessing the condition of buried facilities and utilities such as electrical communication and water supplies including underground fibre optic or pipelines and detecting the location, depth and shape of buried object are carried out using ground digging process. This method has been considered to be less efficient and effective because it takes a long time to get the results and furthermore it contributes delays in the service, increased cost, public inconvenience, and not to mention potential damage to the soil structure as well as excavation errors during the service. Currently, one effective method to facilitate the detection of buried objects called Radar Detection and Ranging (RADAR) system has been applied widely in engineering works. One of the radar implementations that can be used to detect objects below ground level in a certain depth is Ground Penetrating Radar (GPR). The GPR is a geophysical method that used to mainly to facilitate the works in detection and observation of the location, the depth, the shape and the condition of objects buried underground or inside a building. The information about the objects and their condition can be obtained more quickly and easily and likewise, damages on the soil can be avoided as it is non-destructive [1].

GPR works on frequencies of 10 MHz - 3 GHz and uses electromagnetic radiation in microwave wave (UHF / VHF frequency) of the radio wave spectrum [2]. GPR consists of a control unit, a transmitter antenna, receiver antenna, appropriate data storage, and display equipment. The working principle of GPR is radiating electromagnetic wave through transmitter antenna and penetrating it into the soil surface. When the electromagnetic wave hits an object that has a different permittivity constant with the ground, the wave will reflected and it produces an “echo “ signal which then is received by a receiving antenna. The ”echo” signal will pass through the amplifier and filter, then it will be processed by signal processing and the data results will be displayed [3]. The position and shape of the object will be known and detected from the reflected signals that are continuously sent by the object. Detecting objects with certain depths and shapes can be done optimally only using impulses of a certain duration. To detect and find out the depth and size of objects below the surface, a GPR must have a high-resolution value. The resolution requirements used to affect one part of the GPR system block, the antenna.

Antenna is one of the most important parts for the accuracy and performance of GPR. The antenna used for GPR has different specifications from the antennas in general. The antenna needed is the one antennas that can transmit and receive time pulses with short duration, because the duration of the antenna pulse in the time domain is related to the range of resolution and depth of penetration. There are two part of short pulse in time domain that transmitted by the antenna, namely the main pulse and the tail pulse. The tail pulse, also known as late time ringing is an internal reflection wave that causes a masking effect which affects the detection accuracy and resolution level [4]. In addition, radiation patterns of antennas with near or medium field characteristics are more needed, because if you use far-field radiation patterns it cannot be used in data processing, and different positions are still in the near or middle area of the antenna. These specifications can be fulfilled with an antenna that has a wide bandwidth with narrow pulse width and minimum late time ringing.

The previous studies [5] discussed the design of ultra wideband antennas with circular monopole patches. This research explained that the antenna was designed with half and defected ground plane that could cover frequencies from 0.5 to 3 GHz. This antenna is suitable for GPR applications because it has a wide bandwidth. In addition, the antenna has a simple design which can facilitate the detection of underground objects accurately.

The research [4] elaborated antenna specifications that were suitable for GPR application and also compared three types of antennas namely the spiral antenna, TEM horn and shielded broadband dipole for GPR. The results of the comparison indicated that the shielded broadband dipole was the most suitable one as it satisfied the two antenna concepts for GPR, it is has small antenna dimensions and the dipole arm has an elliptical shape that can widen the bandwidth of the antenna. The other research [6] also studied the comparison of several antenna designs such as vivaldi antenna, horn antenna, bowtie antenna and others. The comparison was conducted to get a suitable antenna to detect the depth of penetration and also to asses the resolution of imaging in the application of GPR. The comparison parameters were the bandwidth and gain values obtained from each antenna. The result of the antenna comparison was that the bowtie antenna design fulfil the bandwidth requirements for GPR application because it can cover both of low and high frequencies but the gain is not too high like other antennas.

Several studies have been conducted on bowtie antennas for UWB applications in order to meet the antenna specifications on GPR. In the study [7], the bowtie antenna design adopted was a-two sectorial bowtie dipoles that could produces an ultrawide bandwidth with a relative bandwidth of 108.5% based on the range from the lower frequency to the upper frequency. Based on previous studies [8][9] confirming that the double side bowtie antenna design and also the same bowtie antenna design with the addition of a tapered structure on the ground plane can cover the frequency range from 3.1 to 10.6 GHz with the bandwidth value obtained at 7.5 GHz. Another method used to widen the bandwidth that can cover the lower frequency with a small dimension antenna is by modifying the arm length and flare angle size on the bowtie antenna. The bandwidth achieved in the research [10] was 1.7 GHz with frequency range from 1 GHz - 2.7 GHz with antenna dimensions of 75x90 mm and flare angle size of 45 degrees while in research [11] bowtie antenna design with 35 degree flare angle and dimensions of 110x70 mm could cover the frequency range from 0.9 to 1.5 GHz and the obtained bandwidth value of 0.6 GHz.

Broadening the bandwidth of the antenna can be done by various methods, one of them is the self-complementary method. Based on the research [12] discussing about comparing several methods such as miniature slots, folded slots, self-complementary and others, it concluded that the bandwidth obtained using the self-complementary method is wider than the other methods. The research also discussed the self-complementary design of H-antenna which produces 81.3% relative bandwidth with a range frequency of 1.35-3.2 GHz (2.3:1) while the research [13] made improvement from [12] where percentage of the increasing bandwidth that obtained was 25% with detailed coverage of the range of frequencies from 1.2-3.42 GHz (3.05:1) with a relative bandwidth of 101.3%. Some research on self-complementary methods have also been carried out with various forms of antenna design used. The research [14] described the implementation of self-complementary method for the form of rectangular antennas that cover the frequency range from 3.08-10.98 GHz with a bandwidth of 7.9 GHz, meanwhile the other form of antenna design is planar inverted cone antenna, which based on the research of the antenna, it produces ultra-wide bandwidth (3.1-10.6 GHz)[15]. Self-complementary with bowtie antennas were also discussed in several studies such as research [16] comparing traditional bowtie antenna designs with bowtie antenna designs using self-complementary methods where the antenna design results in a wide frequency range from 2.75 GHz - 11.5 GHz that met UWB specifications with an antenna structure which is easy to make and has a simple design. It is different from traditional bowtie antenna designs which requires complex matching parts to get wide bandwidth. The research [17] of self-complementary bowtie antennas that were designed and realized to generate bandwidth from 2.8-10 GHz was proposed for UWB applications

Reducing the value of the late time ringing can be done by various methods, one of them is by resistive loading. Based on the previous research [18] explains that the comparison of the value of late time ringing on dipole antenna without resistive loading, with the addition of resistive loading and resistive loading and also capacitive based on the Wu-king profile theory where the results of minimum late time ringing are obtained using resistive loading with detail value of -37.88 dB. This research [19] also discussed resistive loading on dipole-spiral antenna design with different constant values or densities to get optimal result for GPR application where resistive loading is attached along the antenna arm to suppress the end time ringing value of the antenna spiral dipole. The results of a spiral dipole antenna design is that the greater the value of k or the further the distance of the resistor results in the minimum value of late time ringing.In research [20][21] discussed resistive loading on the design of the half elliptical antenna and bowtie antenna. The results of the resistive loading showed that the more resistor components are used, the less late time ringing value where the late time ringing value produced by using one resistor component is -27,163 while the late time ringing value is -30,439 dB if using 10 resistor components. In addition, the number of resistor components also affects the widening of the antenna bandwidth where the bandwidth value increases by 62.5 MHz from 1087.2 to 1149.7 MHz.

It can be concluded from previous studies [4] to [21] the antenna used for GPR must meet UWB antenna specifications with small dimensions and minimum late time ringing values. Therefore, this undergraduated thesis carries out the design and realization of a bowtie antenna using a microstrip line feeding with the addition of a self complementary method to widen the bandwidth and resistive loading to suppress late time ringing values. Antenna design is done using a simulator and fabrication of the antenna using FR-4 substrate material with a material thickness of 1.6 and a relative permittivity value of 4.3.

1.2 Problem Formulation

The problem formulation in this undergraduate thesis is that an antenna without a minimum ringing level value can cause less optimal detection. Consequently, the data obtained will be insufficient in terms of accuracy, including the resolution and the depth of the object being detected.

1.3 Purpose of Research

The purpose of this research is to design and realize the transmitter and receiver parts of electromagnetic waves, namely antennas to meet GPR system blocks with wide bandwidth and low ringing level values that can be used for object detection and analyzing measurement results with test parameters

1.4 Scope of Research

The scope of this thesis is as follows:

1. Research is focused on designing and the realization the antenna, not the whole system.
2. Research focus on designing and realization of bowtie antenna with a frequency 1300 - 2200 MHz as an antenna for GPR system.
3. Antenna design does not include shielding structures for antennas.
4. The antenna parameters measured and analyzed such as Voltage Standing Wave Ratio (VSWR), Bandwidth and Late-time ringing.
5. The focus of this research is on bandwidth and late time ringing parameters on the antenna.
6. This research does not discuss the process of detecting GPR objects in depth and the antenna will not tested on buried objects.
7. Designing Antenna is done using software.

1.5 Research Metodology

1. Literature Study

   The aims of this step are to collect and identify study literature from journals, paper, the previous research and books related to Ground Penetrating Radar (GPR) system, design antenna for GPR, antenna Bowtie to support the process of preparing this final assignment.

2. Designing and Simulation

   Designing an antenna based on the initial calculation that forms an antenna dimension which is then simulated using software to make it easier to see the antenna performance that has been designed.

3. Realization

   The antenna realization process is based on the size of the simulated design that has been made with a predetermined material.

4. Measurement

   Measuring the antenna parameters needed to determine the quality of the performance of the antenna. The measurement process is carried out in 2 step, namely the parameters to measure the value of VSWR and Bandwidth and the second is the measurement of late time ringing.

5. Analysis

   The analysis is carried out after the measurement process has been carried out. The analysis compares the results obtained during design and simulation with results from realized antenna measurements.

1.6 Structure of This Thesis

The rest of this thesis described as follows:

1. Chapter 2 LITERATURE REVIEW

   This chapter describes the theories, tools, and equipment related in this research.

2. Chapter 3 DESIGN AND SIMULATION This chapter describe the antenna design process is explained and also the antenna design modelling.

3. Chapter 4 MEASUREMENT AND ANALYSIS

   This chapter contains an analysis of the antenna parameter measurements reviewed such as VSWR, bandwidth,and ringing level.

4. Chapter 5 CONCLUSIONS AND SUGGESTIONS
   This chapter contains conclusions drawn from the design process and analysis and suggestions for further research development.