A MULTI-BAND INTEGRATED ELECTROMAGNETIC FIELD DETECTION SYSTEM

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ABSTRACT

This project is about A Multi-Band Integrated Electromagnetic Field Detection System where it can be used, how it can detect and compare the radiation with its safety level of electromagnetic. Electromagnetic radiation has been a common concern in most developed and developing countries in terms of the hazard it poses upon human's health and its capabilities of reducing efficiency of electrical and electronic devices in its surrounding. This system is designed to help human in daily life to avoid the exposure to electromagnetic radiation at telecommunication base station, hospitals or any placed exposed to radiation. The system is capable of detecting the level of electromagnetic radiation (in volts/meter) by the antenna at the frequencies of 0.9GHz, 1.8GHz and 2.1GHz and compared with the safety limits set by international standard (ICNIRP). Experimental setup has been carried out using GTEM cell and RF measurement instruments to validate the efficiency and preciseness of the designed electromagnetic radiation detector. The designed unit contains receiver stage which is rectangular microstrip patch antenna, detector and amplifier stage which is used to amplify and produce accurate DC voltage, microcontroller circuit which is used to compare the received value with the safety value of electromagnetic radiation and interfacing the hardware with PC using GUI. The output on the PC is an emitting diodes light coloured which is either green for safety, orange for critical or red danger.

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LIST OF SYMBOLS AND ABBREVIATIONS

AC	-	Alternate Current
ADC	-	Analog-to-Digital Converter
AMP	-	Amplifier
AR	-	Anti-Reflecting
CAD	-	Computer-Aided Design
DC	-	Direct Current
DFT	-	Discrete Fourier Transform
DNA	-	Deoxyribonucleic Acid
DXF	-	Drawing Exchange Format
EM	-	Electromagnetic
EMF	-	Electromagnetic Field
FI	-	Finite Integration
GDS	-	Graphic Database System
GND	-	Ground

GTEM	-	Gigahertz Transverse Electromagnetic
Hz	-	Hertz
IC	-	Integrated Circuit
IDE	-	Integrated Development Environment
LED	-	Light Emitting Diode
NC	-	Not Connected
NRPB	-	National Radiological Protection Board
PIC	-	Programmable Interface Controller
RMS	-	Root Mean Square
RCS	-	Radar Cross Section
RF	-	Radio Frequency
RISC	-	Reduced Instruction Set Computer
3D	-	Three-Dimensional

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CHAPTER 1

INTRODUCTION

1.1 Project Background

Exposure to electromagnetic fields is not a new phenomenon. However, during the 20th century, environmental exposure to man-made electromagnetic fields has been steadily increasing as growing electricity demand, ever-advancing technologies and changes in social behaviour have created more and more artificial sources. Everyone is exposed to a complex mix of weak electric and magnetic fields, both at home and at work, from the generation and transmission of electricity, domestic appliances and industrial equipment, to telecommunications and broadcasting [1].

Electromagnetic fields (EMF) occur in nature and thus have always been present on earth. However, during the twentieth century, environmental exposure to man-made sources of EMF steadily increased due to electricity demand, ever-advancing wireless technologies and changes in work practices and social behavior [1].

Electric and magnetic fields are a basic force of nature (like gravity), generated by electricity. They are found in nature, where they are created by such things as lightning and static electricity or manmade fields which are found wherever people use electricity, such as near power lines and electrical appliances. On the other hand it can be found almost everywhere [2].

Electric fields are created by differences in voltage, the higher the voltage, the stronger will be the resultant field. Magnetic fields are created when electric current flows, the greater the current, the stronger the magnetic field. An electric field will exist even when there is no current flowing. If current does flow, the strength of the magnetic field will vary with power consumption but the electric field strength will be constant [3].

Electric and magnetic fields (EMF) are areas of energy that surround any electrical device. Power lines, electrical wiring, computers, televisions, hair dryers, household appliances and everything else that uses electricity are sources of EMF. The magnetic field is not blocked by buildings so outdoor sources like power lines can add to the EMF inside your home. However, the field decreases rapidly with distance so that most homes are too far from high voltage lines to matter [4].

Before proceeding into depth matters regarding the topic, a good understanding must be made on meanings of the terms involved. First and foremost, it must be noted that there is a wide variety of terms associated with Electric and Magnetic fields (EMF). The differences between these terms will be highlighted as to avoid any confusion and misconceptions concerning EMF. Table 1.1 will explain briefly on each of the terms involved.

Table 1.1: Differences between Electric Field, Magnetic Field and Electromagnetic Field

Electric field	1. Electric fields arise from voltage. 2. Their strength is measured in Volts per metre (V/m) 3. An electric field can be present even when a device is switched off. 4. Field strength decreases with distance from the source.
Magnetic field	1. Magnetic fields arise from current flows. 2. Their strength is measured in amperes per meter (A/m). 3. Magnetic fields exist as soon as a device is switched on and current flows. 4. Field strength decreases with distance from the source. 5. Magnetic fields are not attenuated by most materials.
Electromagnetic field	Electromagnetic radiation has been around since the birth of the universe; light is its most familiar form. Electric and magnetic fields are part of the spectrum of electromagnetic radiation which extends from static electric and magnetic fields, through radiofrequency and infrared radiation, to X-rays.

Electromagnetic fields are present everywhere in our environment but are invisible to the human eye. Electric fields are produced by the local build-up of electric charges in the atmosphere associated with thunderstorms. The earth's magnetic field causes a compass needle to orient in a North-South direction and is used by birds and fish for navigation. Besides that the natural sources the electromagnetic spectrum also includes fields generated by human-made sources: X-rays are employed to diagnose a broken limb after a sport accident. The electricity that comes out of every power socket has associated low frequency electromagnetic fields. And various kinds of higher frequency radio waves are used to transmit information – whether via TV antennas, radio stations or mobile phone base stations [3].

Exposure limit has been specified by the World Health Organization (WHO) and the International Commission on Non-Ionizing Radiation Protection (ICNIRP). Electric and magnetic fields (EMF) are invisible lines associated with the use of electric power.
The time-varying electromagnetic fields produced by electrical appliances are an example of extremely low frequency (ELF) fields. ELF fields generally have frequencies up to 300 Hz. Other technologies produce intermediate frequency (IF) fields with frequencies from 300 Hz to 10 MHz and radiofrequency (RF) fields with frequencies of 10 MHz to 300 GHz. The effects of electromagnetic fields on the human body depend not only on their field level but on their frequency and energy. Our electricity power supply and all appliances using electricity are the main sources of ELF fields; computer screens, anti-theft devices and security systems are the main sources of IF fields; and radio, television, radar and cellular telephone antennas, and microwave ovens are the main sources of RF fields. These fields induce currents within the human body, which if sufficient can produce a range of effects such as heating and electrical shock, depending on their amplitude and frequency range. (However, to produce such effects, the fields outside the body would have to be very strong, far stronger than present in normal environments) [5].

Low-frequency electric fields influence the human body just as they influence any other material made up of charged particles. When electric fields act on conductive materials, they influence the distribution of electric charges at their surface. They cause current to flow through the body to the ground. Low-frequency magnetic fields induce circulating currents within the human body. The strength of these currents depends on the intensity of the outside magnetic field. If sufficiently large, these currents could cause stimulation of nerves and muscles or affect other biological processes [6].

High-frequency fields heat the human body. The degree of absorption of electromagnetic waves is a function of the frequency and intensity of the field and the type of tissue. The organs with the least blood flow are most endangered, e.g. the eyes. In contrast, the heart and brain are better at handling heat due to their better blood flow.

Potential health effects of man-made EMF have been a topic of scientific interest since the late 1800s,and have received particular attention during the last 30 years.EMF can be broadly divided into static and low-frequency electric and magnetic fields, where the common sources include power lines, household electrical appliances and computers, and high frequency or radiofrequency fields, for which the main sources are radar, radio and television broadcast facilities, mobile telephones and their base stations, induction heaters and anti-theft devices [6].

Despite extensive research over the past 20 years, the health risk caused by EMF exposure remains an open question. Two national research organizations (the National Research Council and the National Institute of Health) have looked at the studies and have concluded that there is not strong evidence that EMF exposures pose a health risk. However, some studies have shown an association between household EMF exposure and a small increased risk of childhood leukemia at average exposures above 3 mG. For cancers other than childhood leukemia, there is less evidence for an effect. For example, workers that repair power lines and railway workers can be exposed to much higher EMF levels than the general public. The result of cancer studies in these workers is mixed. Some studies have suggested a link between EMF exposure in electrical workers and leukemia and brain cancer. Other similar studies have not found such associations. There is also some evidence that utility workers exposed to high levels of EMF may be at increased risk of developing amyotrophic lateral sclerosis. Although the current scientific evidence provides no definitive answers as to whether EMF exposure can increase health risks, there is enough uncertainty that some people may want to reduce their exposure to EMF [4].

1.2 Problem Statement

Humans actually live in an invisible sea of electromagnetic field energy. Subtle energies constantly swirl in and around their bodies, whether or not they were aware of them. The effects of external exposure to EMF on the human body and its cells depend mainly on the EMF frequency and magnitude. At low frequencies, EMF passes through the body while at radio frequencies the fields are partially absorbed and penetrate only a short depth into the tissue. Experimental and epidemiological data from the IF (Intermediate frequency fields) range are very sparse. Therefore, assessment of acute health risks in the IF range is currently based on known hazards at lower frequencies and at higher frequencies. Proper evaluation and assessment of possible health effects from long-term exposure to IF fields are important because human exposure to such fields is increasing due to new and emerging technologies. According to the World Health Organization, there are certain forms of electromagnetic radiation that are unquestionably hazardous to human health. Microwaves cook food by bombarding them with electromagnetic waves. X-rays are a form of electromagnetic radiation that can cause cancer in fairly short order. And gamma rays are electromagnetic waves that can inflict fatal radiation poisoning in seconds. Some individuals report "hypersensitivity" to electric or magnetic fields. They ask whether aches and pains, headaches, depression, lethargy, sleeping disorders, and even convulsions and epileptic seizures could be associated with electromagnetic field exposure. According to New South Wales Government Australia, 1999 “It has not been established that electric fields or magnetic fields of power frequency are harmful to human health, but since there is some evidence that they may do harm, a policy of prudent avoidance is recommended.

The proposed system is to detect electromagnetic radiation. The system has the capability of measuring voltage value of the received electromagnetic radiation and uses that value to identify its equivalent electric field value and compare it with a safety value of electromagnetic. A microcontroller will used inside the detector that capable to compare the detect value with safety value and display the status on the PC screen using GUI. The system displays the status of the electromagnetic radiation by indicating appropriate lights on the PC screen. The system will be duplicated to more than one unit and all units will connect to one PC as network unit to make easy of observation.

1.3 Objectives of the Project

The objectives for this project are:

i. To design a microstrip patch antenna which operates at 0.9GHz, 1.8GHz and 2.1GHz and act as receiver stage of the system.
ii. To design a detector and amplifier circuits which consist of RF logarithmic power detector that performs the task of conversion from AC to DC conversion and a microcontroller use to compares the voltage received from the detector with predetermined values.
iii. To develop a network of three detectors controlled by central unit.
iv. To implement an efficient Graphical User Interface (GUI) for the EMF network.

1.4 Scopes of the Project

This project is divided into six major phases:

i. First involves designing a microstrip patch that operates at 0.9GHz, 1.8GHz and 2.1GHz.
ii. Second the simulation process will occur to simulate the parameters of the antenna such as radiation pattern and return loss by using CST microwave studio followed by the fabrication using FR4 dielectric substrate and measurement for the return loss using Network Analyzer.
iii. Third involves designing and fabrication a detector and amplifier circuits which consist of RF logarithmic power detector that performs the task of conversion from AC to DC.
iv. Fourth involves designing and programmed a microcontroller using PIC16F876A.
v. Fifth involves calibrated using GTEM Cell to find the relationship between electric field received and induced DC voltage.
vi. Finally the duplication and developing a network of three detectors controlled by central unit using GUI.

1.5 Expected Results

i. The device function properly and precisely to detect the EMF radition .
ii. Able to identify whether the exposed electric field at the particular location exceeds the permissible level.
iii. The product can be commercialized.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview

This chapter reviews a brief introduction of electromagnetic radiation, and a brief of previous studies will be conducted on this chapter.

2.2 Theory of Electromagnetic

Electromagnetic field is a physical field produced by electrically charged objects. It affects the behaviour of charged objects in the vicinity of the field. The electromagnetic field extends indefinitely throughout space and describes the electromagnetic interaction. It is one of the four fundamental forces of nature (the others are gravitation, the weak interaction, and the strong interaction) [11].

The field can be viewed as the combination of an electric field and a magnetic field. The electric field is produced by stationary charges, and the magnetic field by moving charges (currents), these two are often described as the sources of the field [11]. The way in which charges and currents interact with the electromagnetic field is described by Maxwell's equations and the Lorentz force law.

The most intense and widespread electromagnetic radiation produced by man which is many times stronger than from natural sources is in the extremely low frequency (ELF) spectrum. In 1989, the average intensity of the background man-made

ELF magnetic fields was about ten times stronger than that resulting from all natural planetary and cosmic events, doubling the ELF fields monitored less than a decade earlier. A spectrum analysis done in Ottawa in 1982 showed radiation from 60 hertz power lines, hydro stations, 10 hertz Soviet radar emissions, and signals from the Soviet Union, Japan, China, Europe and Africa [12].These all contribute to the changes we see today. This permeates our homes, work places, industries and our outdoors and it increases every year as we pollute more and more electromagnetically, and creates a tremendous stress to all living systems. Since all living organisms on earth are exposed to electromagnetic radiation, it is urgent to establish standards of acceptable exposure levels for various frequencies of electromagnetic radiation. Cancer, birth defects, decreased immunity to disease even new sicknesses have been linked to extended exposure to electromagnetic fields of specific frequencies and intensities. Perhaps this may account for the much higher susceptibility to death from AIDS in regions of highest electromagnetic pollution.

Studies published in 1984, showed that exposure to harmful electromagnetic frequencies resulted in altering the behaviour of cells, tissues, organs and organisms; altered hormone levels, altered cell chemistry, altered immune processes, affected calcium ion bonding in cells, modified human brain waves, caused defects in chick embryos, and caused sterility in male animals [12]. They also found that certain diseases can be cured by applying specific extreme low frequency levels. Scientists statistically linked ordinary power lines and commonly used household devices to an increase in human cancer. They found that if human beings or animals came within a certain range of electric power lines, which is considered to be safe, they augmented the field. Ten thousand volts per meter is considered safe because conventional research states that voltages higher than 10,000 volts per meter are strong enough to penetrate the skin and have possible biological effects on living cells [13].Although the field is 10,000 volts, on the skin surface it is 18 times higher. Even by conventional logic, safety levels should be 18 times higher than existing levels.

2.3 ICNIRP definitions and limits

The main objective of ICNIRP is to establish guidelines for limiting EMF exposure that will provide protection against known adverse health effects. Two classes of guidance are presented in frequency between 1 Hz to 10 GHz [14]:

i. Basic restrictions: Restrictions on exposure to time-varying electric, magnetic, and electromagnetic fields that is based directly on established health effects. Depending upon the frequency of the field, the physical quantities used to specify these restrictions are current density (J), specific energy absorption rate (SAR), power density (S) and internal electric field strength (E_i) which is the electric field affects the nerve cells and other electrically sensitive cells [14].

ii. Reference levels: These levels are provided for practical exposure assessment purposes to determine whether the basic restrictions are likely to be exceeded. Most reference levels are derived from relevant basic restrictions using measurement and/or computational techniques but some address perception (electric field) and adverse indirect effects of exposure to EMF. The derived quantities are electric field strength (E), magnetic field strength (H), magnetic flux density (B) and currents flowing through the limbs (IL). The quantity that addresses indirect effects is the contact current (Ic). In any particular exposure situation, measured or calculated values of any of these quantities can be compared with the appropriate reference level. Compliance with the reference level will ensure compliance with the relevant basic restriction. If the measured or calculated value exceeds the reference level, it does not necessarily follow that the basic restriction will be exceeded. However, whenever a reference level is exceeded it is necessary to test compliance with the relevant basic restriction and to determine whether additional protective measures are necessary [14].

2.4 Exposure Limits

The ICNIRP standard has exposure limits for electric fields and magnetic fields that are whole-body and time averaged. Exposure limits are given from DC to 300 GHz. Exposure limits for the magnetic (H) field are relaxed below 100 MHz since the exposure limits at lower frequencies are based more on electro stimulation than body heating and both induced and contact currents are related to the strength of the electric field. There are also limits for induced currents and contact currents. Figure 2.1 depicts the exposure limits that have been set by the International Council on Non-Ionizing Radiation Protection (ICNIRP) [15].

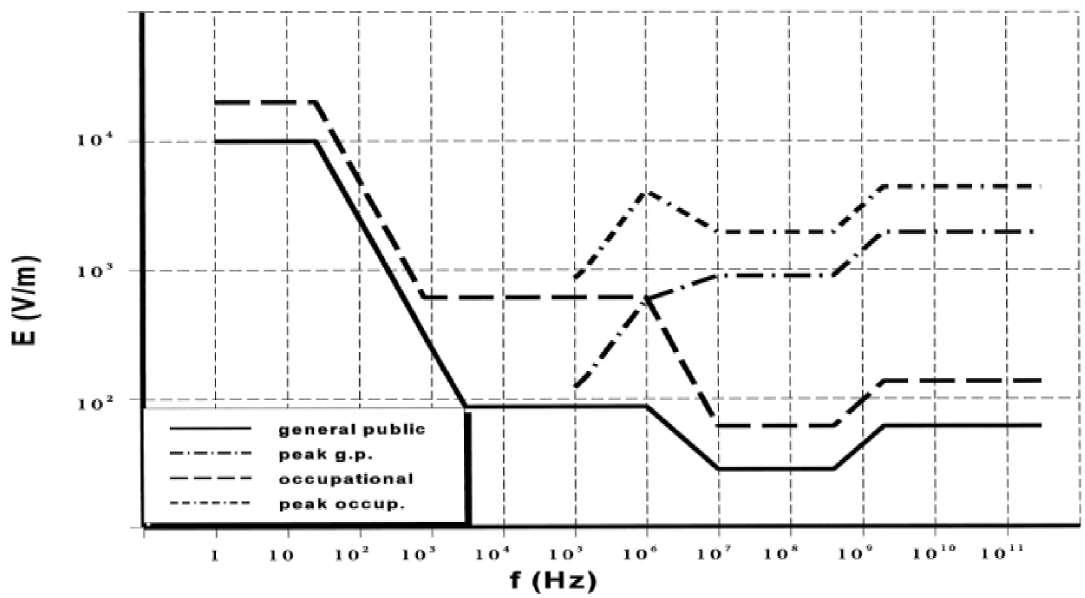

Figure 2.1: Reference Levels for Occupational Exposure to Time-Varying Electric and Magnetic Fields (unperturbed RMS values)

The main objective of this guideline is for the purpose of limiting EMF exposure that will provide protection against known adverse health effects. An adverse health effect causes detectable impairment of the health of the exposed individual or of his or her offspring. A biological effect, on the other hand, may or may not result in an adverse health effect. Studies on both direct and indirect effects of EMF are described; direct effects result from direct interaction of fields with the body, indirect effects involve interactions with an object at a different electric potential from the body. Results of laboratory and epidemiological studies, basic exposure criteria, and reference levels for practical hazard assessment are discussed, and the guidelines presented apply to occupational and public exposure. Guidelines on high-frequency and 50/60 Hz electromagnetic fields were issued by IRPA/INIRC in 1988 and 1990, respectively, but are superseded by the present guidelines which cover the entire frequency range of time-varying EMF (up to 300 GHz). Static magnetic fields are covered in the ICNIRP guidelines issued in 1994 (ICNIRP 1994). In establishing exposure limits, the Commission recognizes the need to reconcile a number of differing expert opinions. The validity of scientific reports has to be considered, and extrapolations from animal experiments to effects on humans have to be made [14].

The restrictions in these guidelines were based on scientific data alone; currently available knowledge, however, indicates that these restrictions provide an adequate level of protection from exposure to time-varying EMF. Two classes of guidance are presented. The basic restrictions: Restrictions on exposure to time-varying electric, magnetic, and electromagnetic fields that are based directly on established health effects are termed "basic restrictions". Depending upon the frequency of the field, the physical quantities used to specify these restrictions are current density (J), specific energy absorption rate (SAR), and power density (S).Only power density in air, outside the body, can be readily measured in exposed individuals.

These levels are provided for practical exposure assessment purposes to determine whether the basic restrictions are likely to be exceeded. Some reference levels are derived from relevant basic restrictions using measurement and/or computational techniques, and some address perception and adverse indirect effects of exposure to EMF. The derived quantities are electric field strength (E), magnetic field strength (H), magnetic flux density (B), power density (S), and currents flowing through the limbs (IL). Quantities that address perception and other indirect effects are contact current (IC) and, for pulsed fields, specific energy absorption (SA). In any particular exposure situation, measured or calculated values of any of these quantities can be compared with the appropriate reference level. Compliance with the reference level will ensure compliance with the relevant basic restriction. If the measured or calculated value exceeds the reference level, it does not necessarily follow that the basic restriction will be exceeded. However, whenever a reference level is exceeded, it is necessary to test compliance with the relevant basic restriction and to determine whether additional protective measures are necessary [14].

Where appropriate, the reference levels are obtained from the basic restrictions by mathematical modeling and by extrapolation from the results of laboratory investigations at specific frequencies. They are given for the condition of maximum coupling of the field to the exposed individual, thereby providing maximum protection. Table 2.1 and Table 2.3 summarize the reference levels for occupational exposure and exposure of the general public, respectively, and the reference levels are illustrated in Figure 2.1. The reference levels are intended to be spatially averaged values over the entire body of the exposed individual, but with the important proviso that the basic restrictions on localized exposure are not exceeded. For low-frequency fields, several computational and measurement methods have been developed for deriving field-strength reference levels from the basic restrictions. The simplifications that have been used to date did not account for phenomena such as the inhomogeneous distribution and anisotropy of the electrical conductivity and other tissue factors of importance for these calculations [14].

Table 2.1: Reference Levels for Occupational Exposure to Time-Varying Electric and Magnetic Fields (Unperturbed RMS Values) [14].

Frequency Range (F)	**Electric Field (E) (V/m)**	**Magnetic Field (H) (A/m)**	**Power Density (S) (E,H Fields) (mW/cm^2)**
<1 Hz	-	163×10^3	-
1 – 8 Hz	20,000	$163 \times 10^3/f^2$	-
8 - 25 Hz	20,000	$2.0 \times 10^4/f$	-
0.025 – 0.82 kHz	500/f	20/f	-
0.82 - 65 kHz	610	24.4	100; 22,445
0.065 - 1 MHz	610	1.6/f	100; $100/f^2$
1 – 10	610/f	1.6/f	$100/f^2$
10 - 400 MHz	61	0.16	1.0
400 – 2,000 MHz	$3f^{½}$	$0.008f^{½}$	f/400
2 – 300 GHz	137	0.36	5.0

The frequency dependence of the reference field levels is consistent with data on both biological effects and coupling of the field.

Table 2.2: Reference Levels for Current Induced in Any Limb [14].

Frequency Range	**Maximum Current (ma)**	
	Occupational	**General Public**
<2.5 kHz	1.0	0.5
2.5 - 100 kHz	0.4f	0.2/f
100 kHz – 110 MHz	40	20

Table 2.3: Reference Levels For General Public Exposure to Time-Varying Electric and Magnetic Fields (Unperturbed RMS Values) [14].

Frequency Range (F)	**Electric Field (E) (V/m)**	**Magnetic Field (H) (A/m)**	**Power Density (S) (E,H Fields) (mW/cm^2)**
<1 Hz	-	3.2×10^4	-
1 – 8 Hz	10,000	$3.2 \times 10^4/f^2$	-
8 – 25 Hz	10,000	4000/f	-
0.025 – 0.82 kHz	250/f	4/f	-
0.8 – 3 kHz	250/f	5	-
0.82 - 65 kHz	87	5	2.0; 995
0.065 - 1 MHz	87	0.73/f	2.0; $20/f^2$
1 – 10	$87/f^{½}$	0.73/f	2.0/f; $20/f^2$
10 – 400 MHz	28	0.073	0.2
400 – 2,000 MHz	$1.375f^{½}$	$0.0037f^{½}$	f/2000
2 – 300 GHz	61	0.16	1.0

2.5 Effects on General Health

Some members of the public have attributed a diffuse collection of symptoms to low levels of exposure to electromagnetic fields at home. Reported symptoms include headaches, anxiety, suicide and depression, nausea, fatigue and loss of libido. To date, scientific evidence does not support a link between these symptoms and exposure to electromagnetic fields. At least some of these health problems may be caused by noise or other factors in the environment or by anxiety related to the presence of new technologies.

2.6 Health and Safety Measure for Electromagnetic Radiation

The National Radiological Protection Board (NRPB) has published guidance on exposure to non-ionizing radiation. This document recommends investigation levels which set the power density above which people should not normally be exposed. In the relevant frequency range this is 100 watts per square meter ($100\ W/m^2$), this is the same as 10 milliwatts per square centimeter ($10mW/cm^2$). As such, it is not safe for humans to be exposed by electromagnetic field which has a power density above$10mW/cm^2$. This value is used as a guideline when comparing with the detected field. When the particular detected field's power density is higher or near to$10mW/cm^2$, the alert device is triggered [14].

2.7 Frequency Chosen for the Project

The frequencies of 0.9GHz, 1.8 GHz and 2.1 GHz is chosen for this project due to their applications in antennas used at telecommunication base stations and also to make the system easy to use everywhere in the world because not all counties using same frequency for example in Malaysia they use0.9GHz and in Korea they use 2.1GHz by selecting these frequencies, the system will be easy to use everywhere. The system is designed to detect radiation in the frequencies of 0.9GHz, 1.8 GHz and 2.1 GHz which has commercial value in the telecommunication industry where people who works at the base station or lives in a residential area near to a telecommunication base station are highly exposed to electromagnetic radiations. Hence, the system is designed in a manner that it can detect radiation from antennas located at the telecommunication base station that operates using the frequencies of 0.9GHz, 1.8 GHz and 2.1 GHz.

2.8 Previous Research on Electromagnetic Radiation Detector

2.8.1 Electromagnetic Radiation Detector Badge

An electromagnetic radiation detector badge has been proposed by Bernard Lanoe and Elisabeth de Metz. An electromagnetic radiation detector were developed and attached inside a batch similar design. The radiation receiver used to detect the electromagnetic field is a two dipole antenna and the voltage detector used is a NPN transistor [17]. The schematic diagram of the radiation detector is shown in Figure 2.2.

A full-wave bridge rectifier is used to rectify the AC input signal from the antenna to a DC output which later will filter by a resistor and capacitor before the signal is connected through a potentiometer to the base of an NPN transistor connected in a grounded or common emitter configuration. Transistor acts as an electronic threshold amplifier switch and the switching threshold is defined by the position of the tap of potentiometer. The collector of transistor is connected to the input terminal of an electroluminescent diode. In operation, when the level of radiation received by antenna has been such that the resultant DC voltage at the base triggers transistor, diode is energized by lighted up and emitted a red light.

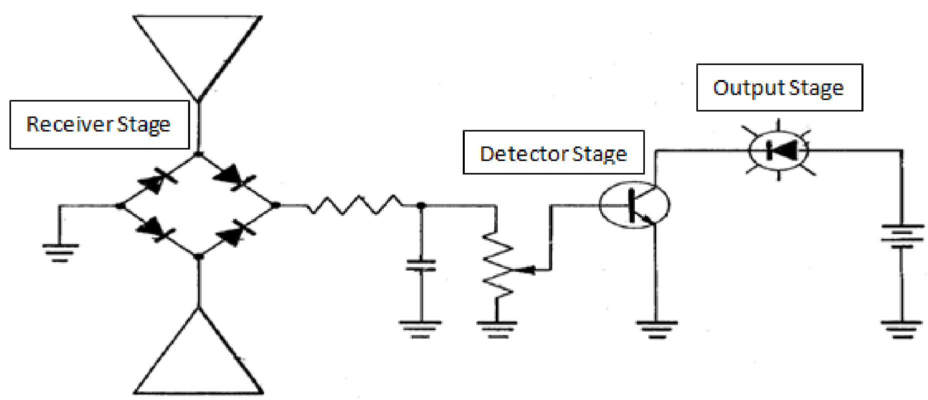

Figure 2.2: Schematic Circuit Diagram of the Detector

2.8.1.1 Advantage/Disadvantage of the Research with this Project

Even though the proposed design above can be used to detect electromagnetic field, but there are several disadvantage on it. First, the two dipole antenna used is bulky and not suitable to be used in a hand held device or a badge as proposed by the inventor. Microstrip patch antenna is more suitable in fulling such task due to its simplicity, less expensive to manufacture, more compatible and require less space. Second, the rectifying circuit used is too simple where it is not possible to rectify and produce a smooth and precise DC voltage signal. The resultant DC voltage signal produced by the above mentioned circuit could be inaccurate. Third, the radiation detector could not indentify whether the detected electromagnetic field is in safe exposure level or not. Hence, the proposed design does not stand for its name as electromagnetic radiation detector but more to just an ordinary electromagnetic field detector.

2.8.2 Electromagnetic Field Detector

The field detector was designed [18] in four basic parts: a probe, an amplifier, a power supply, and headphones. The schematic of the designed circuit is shown in Figure 2.3. A radial type 950uH inductor is used as the device to sense the electromagnetic fields produced. The signal is then sent through a differentiator consisting of an operational amplifier with a negative feedback loop. A potentiometer is placed within the loop to control the gain of the amplifier stage. A pair of headphones is used to hear the amplified signal, which sounds like a 60Hz buzz. The operational amplifier is powered by a 12V DC power supply connected to a SPST switch. The entire circuit is enclosed in a black plastic box with the switch, potentiometer, headphone jack and probe wire external to the box. The probe itself uses an empty pen tube to hold the radial inductor. There were several capacitors used for AC and DC coupling purposes. Capacitor C1 AC couples the input source (the probe signal) into the amplifier stage. C2 acts as a grounding capacitor, whereas C3 again is used to AC couple the output signal to the headphones. C4 is used to DC couple the supply voltage to the amplifier supply pins. Finally R1 and R2 are used as a voltage divider to provide 6V at pin 3 of the op-amp.

The disadvantage of this system doesn't have the ability to indentify whether the detected electromagnetic field is in safe exposure level or not. The system may doesn't have the ability to produce smooth DC due to the simplest of the circuit and the effect of active component at higher frequency.

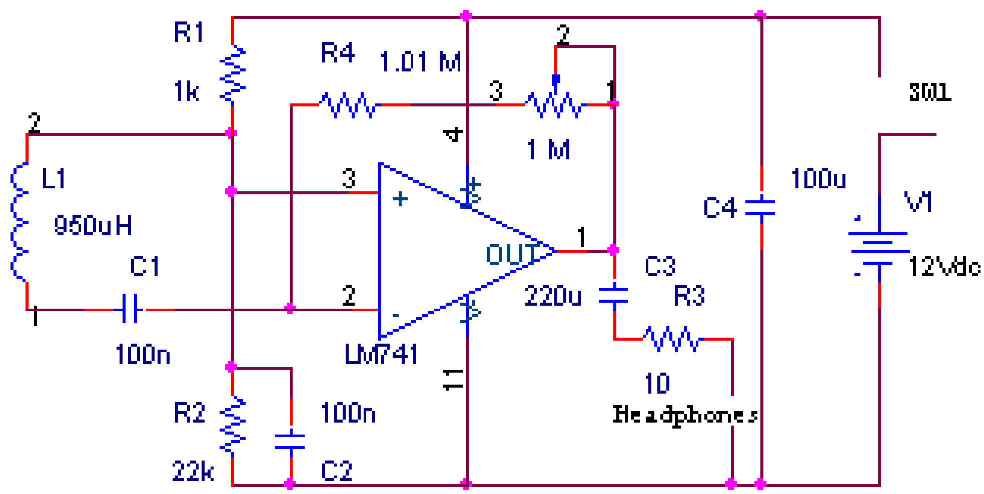

Figure 2.3: Electromagnetic Field Detector

2.8.3 Electromagnetic Radiation Detector Using Electric Field Probe

An electromagnetic radiation detector using electric field probe has been proposed by Howard I. Bassen and Glenn S. Smith. They proposed an electromagnetic radiation detector using an electric field probe consisting of a dipole antenna, Radio Frequency (RF) detector, and non-perturbing transmission line and readout device [19]. The schematic of the probe is shown in Figure 2.4.

The operation of the probe is fairly simple. For a continuous-wave incident field with a particular frequency, the antenna produces an oscillating voltage across the detector at its terminals. Due to the nonlinear characteristic of the detector, a signal with a DC component proportional to the square of the amplitude of the incident field is developed at the detector. This signal is filtered, and the DC component is conveyed over the transmission line to the monitoring instrumentation. Thus, a signal proportional to the square of the amplitude of the incident field is measured. The suggested detector in the probe was an unbiased point contact or schottky barriediode operating in the square-law region, or a thermocouple junction.

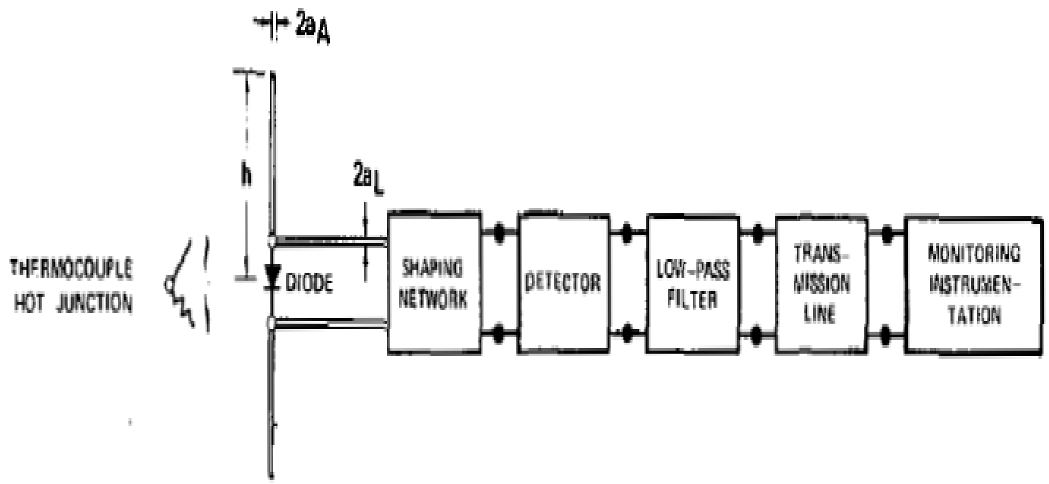

Figure 2.4: Schematic of the Electric Field Probe

2.8.3.1 Advantage/Disadvantage of the Research with this Project

The suggested electromagnetic radiation detector using electric field probe above is considerable for electric field measurement. In fact, most commercial electromagnetic field detector device uses the above basic principle to operate. But even so, the proposed detector is not suitable for a small handheld device due to its transmission line and monitoring instrument. This design is suitable for measuring the field distribution in chambers used for radiated immunity test but not suitable for a handheld device. Furthermore, this device has the same disadvantage as the previous research, it does not has the system to calibrate the measured resultant signal and compare the signal with a pre-determined signal and alert the user about the safety level of the exposed electromagnetic radiation.

2.8.4 Electromagnetic Field Sensor

This is the circuit diagram of a very sensitive electromagnetic field sensor which can sense electromagnetic field from 40Hz to 140Hz. The low noise opamp LF351 and associated components forms the pick-up section. 1uH coil L1 is used for sensing the field and the IC1 performs the necessary amplification. If the picked electromagnetic field is in the audio frequency range, it can be heard through the head phone Z1.There is also a meter arrangement for accurate measuring of the signal strength. Transistor Q1 performs additional amplification on the picked signal in order to drive the meter as shown in Figure 2.5.

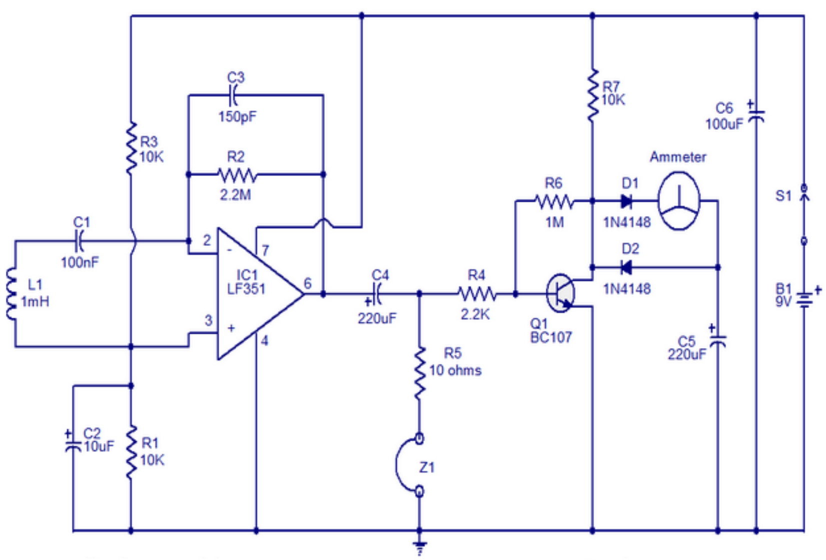

Figure 2.5: Electromagnetic Field Sensor

2.8.5 Electromagnetic Field Detector Bracelet

In [20] a cost-effective implementation of a wearable sensor was present to detect and display the strength and other characteristics of ambient electromagnetic fields. One implementation pursued in this work was the detection of the capacitively-coupled electric field emanating from a laptop display. The design could offer an instantaneous awareness about surrounding emanations and signals that are “invisible” within the context of use of everyday objects. The proposed design is wearable device, i.e. a bracelet that responds to the non-perceived EMF that surrounds us (see Figure 2.6) that lies beyond human perception.

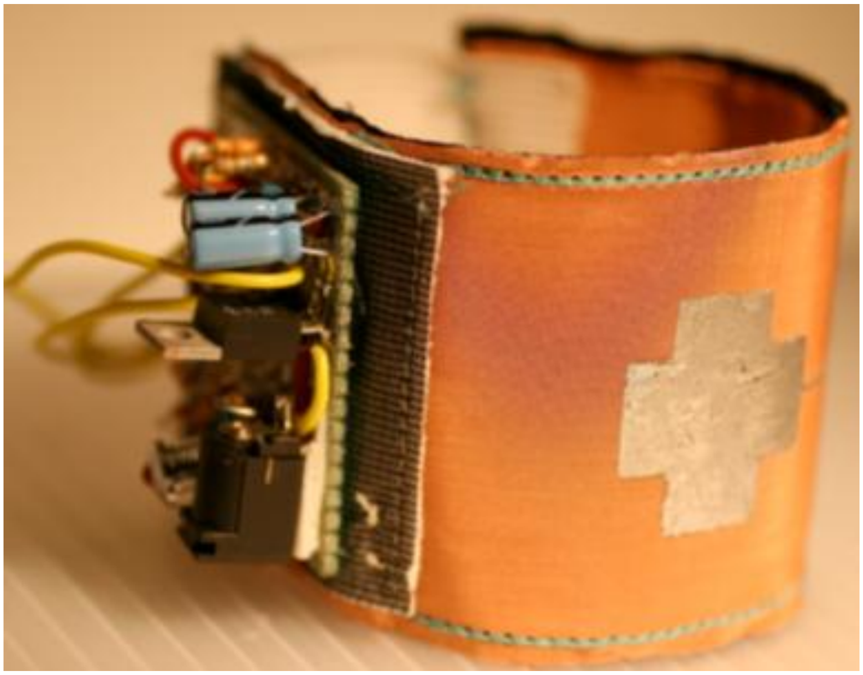

Figure 2.6: The Electromagnetic Field (EMF) Detector Bracelet

2.8.6 Sensitive Electromagnetic Radiation

This circuit is sensitive to low frequency electromagnetic radiation and will detect for example hidden wiring or the field that encompasses a transformer. Pickup is by a radial type inductor, used as a probe which responds well to low frequency changing magnetic and electric fields. Ordinary headphones are used to for detection. The field that surrounds a transformer is heard as a 50 or 60Hz buzz as shown in Figure2.7.

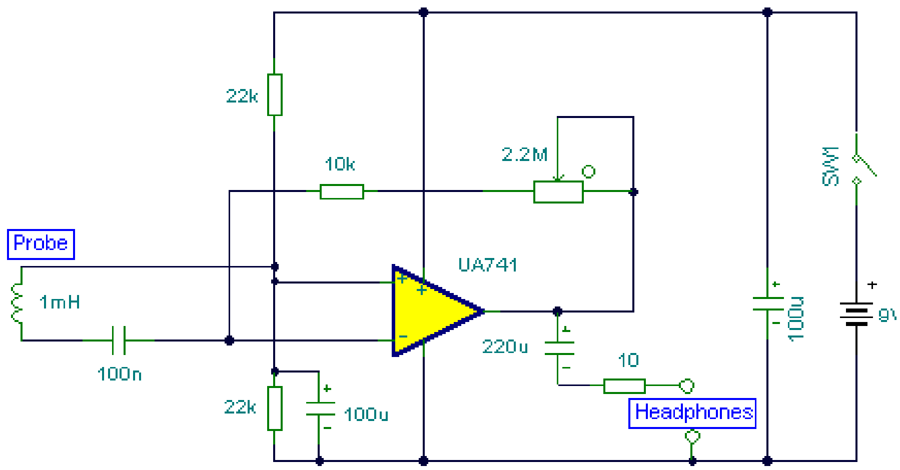

Figure 2.7: Sensitive Electromagnetic Radiation

2.8.7 EMF Detector

This system was design to detect the radiation at 900MHz. but the system was not design successfully and does not work properly [21]. Below is the block diagram for the system as shown in Figure 2.8.

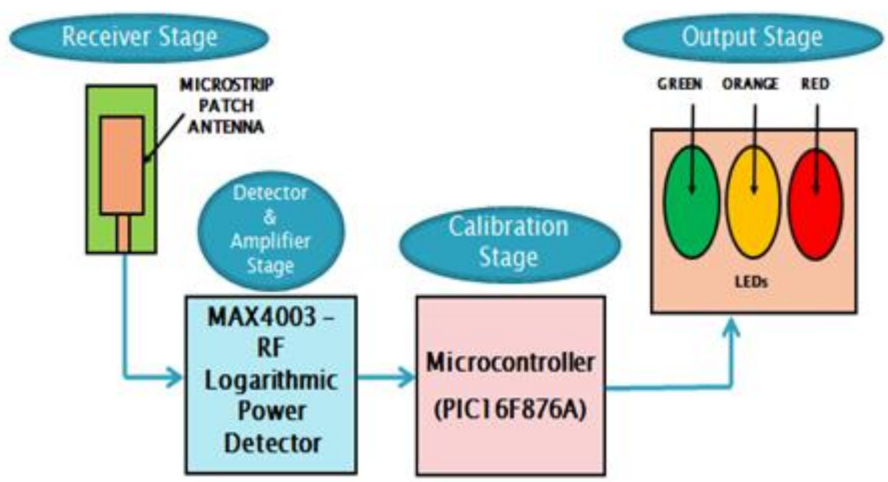

Figure 2.8: EMF Detector.

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