THE EFFECT OF SHIELDING, GROUNDING AND BONDING TO THE ELECTROMAGNETIC COMPATIBILITY OF HIGH EMISSION PRINTED CIRCUIT BOARD

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DEDICATION

To the lighthouse of science, Great Prophet Mohammed peace be upon him,
To my homeland, to my family, to my teachers and to all who helped me.

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ABSTRACT

Electromagnetic Compatibility (EMC) is the capability of the device or the system to perform its work correctly within its electromagnetic environment without causing the introduction of electromagnetic damage to that environment. Radiated Emission (RE) is one of the EMC tests that should be conducted to ensure that the product or equipment do not radiate any unwanted Electromagnetic (EM) to its environment. In this work, three different types of Printed Circuit Board (PCB) designs are studied. The PCBs are less costly and can be easily protected from the impact of the electromagnetic environment from the EM radiation. The effect of two high radiation circuits on each other has been studied and found to be the best way to reduce this bad effect using EMC techniques. Shielding is one of the EMC design to reduce the radiation. However, shielding must be accompanied by grounding to ensure unwanted current has been grounded to the shielded enclosure. Therefore the emission can be reduced an average 10.1 dB μV/m after grounding has been applied. The effect of two equipments without bonding can be useless because non-equipotential occurs. Therefore, bonding has been applied between two enclosures (system), which gave a significant reduction by 8.7 dB μV/m. Based on the study, it shows that the best bonding type is a metal plat joint tightly between two enclosures as compared with big tail wire or braided strap.

ABSTRAK

Keserasian Elektromagnetik (EMC) adalah keupayaan peranti atau sistem untuk melaksanakan kerja dengan betul dalam persekitaran elektromagnet tanpa menyebabkan terhadap persekitaran tersebut. Pembebasan Radiasi (RE) adalah salah satu daripada ujian EMC yang perlu dijalankan untuk memastikan produk atau peralatan tidak memancarkan sebarang Electromagnetic (EM) yang tidak diingini ke persekitarannya. Dalam karya ini, tiga jenis reka bentuk Lembaga Litar Bercetak (PCB) di analisis. PCB sedia ada amat menjimatkan kos tetapi ianya mempunyai potensi mendapat kesan daripada persekitaran elektromagnet. Dua litar yang memberi kesan radiasi yang tinggi di kaji di antar satu sama lain dan kaedah terbaik untuk mengurangkan kesan buruk ini menggunakan teknik EMC telah di analisis. Penghalang metalik adalah salah satu sistem reka bentuk EMC untuk mengurangkan radiasi. Walau bagaimanapun, penghalang metalik mestilah di bumikan untuk memastikan arus yang tidak diingini yang telah dibebankan akan dibumikan. Maka, kaedah ini dapat mengurangkan lebih kurang 10.1 dBμV/m setelah pembumian digunakan. Selain dari itu, kesan dua sistem/produk tanpa ikatan boleh menjadi sia-sia jika tidak bersifat sama keupayaan. Oleh itu, ikatan telah digunakan di antara dua dinding metalik (sistem), yang memberikan pengurangan ketara sebanyak 8.7 dBμV/m. Berdasarkan kajian itu, ia menunjukkan bahawa jenis ikatan terbaik adalah plat logam yang dipasang secara erat antara dua sistem berbanding dengan kawat ekor besar atau tali berikat.

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LIST OF SYMBOLS AND ABBREVIATIONS

EM	-	Electromagnetic waves
EMC	-	Electromagnetic Compatibility
EMI	-	Electromagnetic Interference
EMS	-	Electromagnetic Susceptibility
EME	-	Electromagnetic Emission
ESD	-	Electrostatic Discharge
PCB	-	Printed Circuit Board
CISPR22	-	International Special Commission on Radio Interference
IEC	-	International Electrotechnical Commission
IEV	-	International Electrotechnical Vocabulary
CM	-	Common Mode
DM	-	Differential Mode
SE	-	shielding Effectiveness
RFI	-	Radio Frequency Interference
EN	-	European Standards
RE	-	Radiated Emission
EUT	-	Equipment Under Test
DUT	-	Device Under Test
SAC	-	Semi Anechoic Chamber
DC	-	Direct Current
AC	-	Alternating Current
E_{DM}	-	Differential-Mode Radiation
E_{CM}	-	Common-Mode Radiation
UTHM	-	University Tun Hussein Onn Malaysia
dB	-	Decibel
IT	-	Information Technology

BALL	-	Big Area Long Loop
SAML	-	Small Area Medium Loop
MASL	-	Medium Area Small Loop
f	-	Frequency (MHz)
I	-	The current (constant)
l	-	The length of the cable (cm)
A	-	The loop area of the PCB (cm)
r	-	The distance between antenna and EUT (3m)

CHAPTER 1

INTRODUCTION

1.1 Research Background

At present, the demand for electronic circuits has increased and demand is keep increasing, which has become the source of interest for developers and researchers. Some specifications usually are set as standard in order to ensure product quality. Electromagnetic waves (EM) will be emitted from the device, during the installation and operation of the electrical system. Thus, it is understood that these electromagnetic waves would be interfered to another circuit known as electromagnetic interference (EMI). Therefore, one of the product quality standards requires that EMI be affected. To realize these specifications, EMI enters the relevant circuits [1]. Three things can cause an EMI problem: a signal source creates a kind of noise, there is a noise transmission path, and/or a receiver is sensitive enough to be distorted by noise [24].

Electromagnetic compatibility (EMC) is defined as the ability of an equipment, device or system to operate satisfactorily in its electromagnetic environment without introducing an intolerable electromagnetic disturbance to anything in that environment. Any electronic equipment can emit unintentional signals (i.e., interference with other electronic equipment) and is also affected by the marginal radiation of other electronic equipment (i.e. interference from other electronic equipment). Putting these electronics together without affecting each other

is a challenge. Facing this challenge is a combination of legislation, engineering, and consideration of the needs of others.

Figure1.1. refer to EMC is classified into EMI and electromagnetic susceptibility (EMS). EMI denotes to disorderly electromagnetic energy transmitted from one electronic device or equipment to another, EMS denotes performance immunity against disturbances such as electrostatic discharge (ESD), [2], [3],[4].

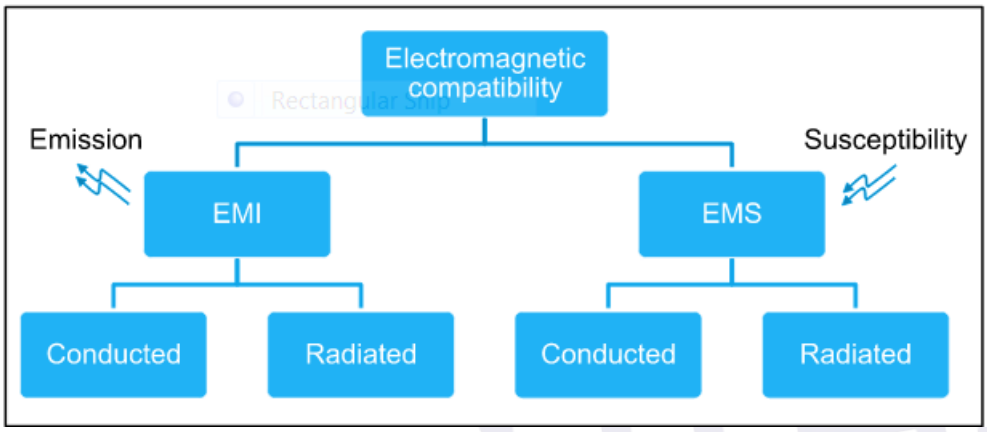

Figure 1. 1: Electromagnetic compatibility diagram [4]

A critical initial stage in controlling EMC in any system project is to assess the electromagnetic environment that the system will sustain. This, in turn, will determine the degree of accuracy that the system components will need to deal with the various emissions applied. Similarly, the components of the systems interact with each other and with the environment, and electromagnetic compatibility should appear in each case. Since interference is propagated through interfaces (including the enclosure as a front, in the same way as cable connections) is a necessary step towards determining the levels of compatibility and testing that will be necessary.

An important tool in EMC control for any system is the control-controlled electronic binding system. In general, the use of any part of the mechanical structure should be avoided as a functional electric current path. It is often necessary to use the interference structure rather than functional grounding, which takes into account electrical considerations. Interconnection requires the management of current interference paths and the reduction of voltage differentials across the interference structure.

The most important facet in dealing successfully with EMC design is that there is a sound understanding of the basic principles of electrical engineering (circuit analysis, electronics, signals, electromagnetic, linear system theory, digital system design, etc.).

1.2 Problem Statement

The electronic circuit must operate optimally in terms of its specifications to the maximum without being affected by external physical factors the emission from other devices so that the purpose of the device can be achieved. The device must be protected from these physical factors to enhance durability and thus ensure long-term viability. System installation may result in significant EMI; this EMI is generated between connecting two systems of devices and equipment of the system or more than to configuration electromagnetic interference environment as shown in Figure 1.2. EMI may interfere with signals of other working devices thus, disrupting their operation. So it is necessary to design a system base EMC compliance. In this project, some techniques to reduce EMI produce from these devices have been proposed such as shielding, grounding and bonding techniques.

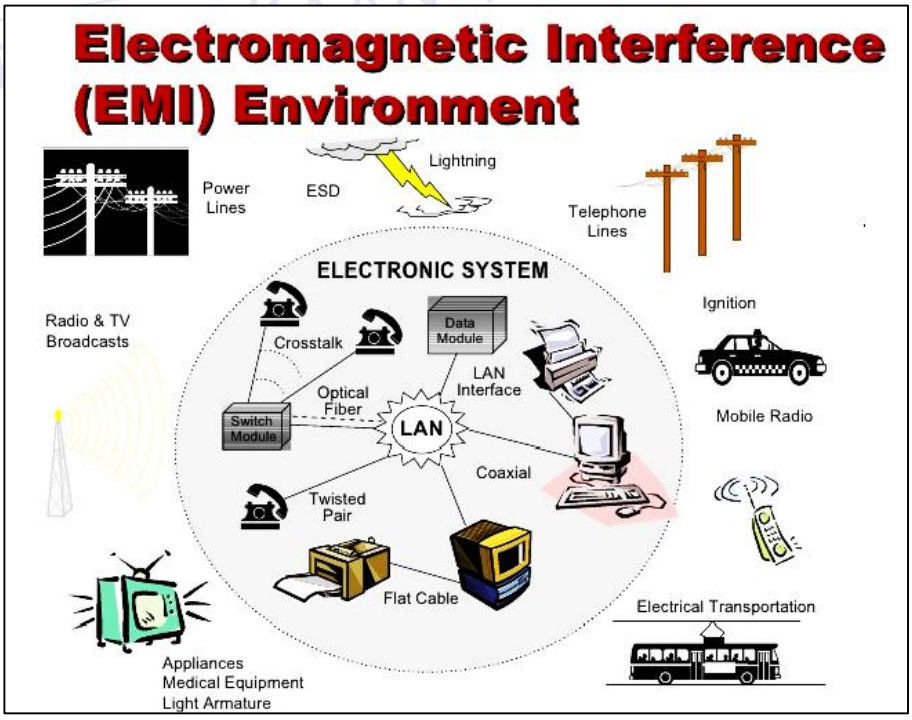

Figure 1. 2: Electromagnetic interference environment

1.3 Objective

In general, this research aims to achieve the elimination of electromagnetic interference through the analysis of electromagnetic radiation itself. On the other hand, in order to achieve this goal, we can achieve a more qualitative objective that includes:

i. To design high emission Printed Circuits Board (PCB) with 20 MHZ digital oscillator for 30 MHz to 1GHz radiation emission.
ii. To investigate and analyze the electromagnetic interference (EMI) produce from two identical PCBs when they are coexisting.
iii. To reduce the EMI from the PCB by using techniques of shielding, bonding, and grounding.

1.4 Research Scope

i. This project is primarily concerned how to reduce electromagnetic interference (EMI) by using Electromagnetic compatibility (EMC) system design techniques shielding, grounding, and bonding.
ii. Design and modeling simple micro printed circuit board (PCB) for high emission is used as a device in the test.
iii. Design three different types of PCBs with different sizes and areas.
iv. Semi Anechoic Chamber (SAC) with its facilities is used for measuring the radiated emission in the center for electromagnetic compatibility University Tun Hussein Onn Malaysia (UTHM).
v. The high of the antenna receiver measurement for RE test was conducted at 1m and 4 m in Semi Anechoic Chamber.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction to Electromagnetic Compatibility

Since the first birth of electronics relatively few items of electronic equipment were in use. But today the number of electronic items has increased on a daily basis. Some of these signals transmit, while many other receivers are sensitive. Others may benefit from digital electronics systems that can result from transient signals. EMC ensures that the operation of the equipment does not affect the electromagnetic environment to the extent that the functions of other devices and systems are adversely affected.

The International Electrotechnical Commission (IEC) and The International Electrotechnical Vocabulary (IEV) have defined electromagnetic Compatibility (EMC) as [1], [2] :“ is the capability of the device or the system to perform its work correctly within its electromagnetic environment without causing the introduction of electromagnetic damage to that environment.”

The explanation of EMC also contains the terms of the EM environment and the inconvenience. The environment of EM it means of (alternative time) the sum of the EM phenomena present in a particular place [1], [2]. This broad interpretation includes not only undesirable EM signals, but also features the propagation of such signals as speed, attenuation, reflections, etc., which in turn are affected by local EM characteristics of materials such as relative permeability and conductivity .

If an electronic device is exposed to severe electromagnetic environment, normal performance will be under uncertainty. Disturbance on the other hand is described as 'any electromagnetic phenomenon which may degrade the performance of device, equipment or system or adversely affect living or inert matter' [1], [2] .The system is considered EMC if it meets these three criteria:

1. Does not cause interference with other systems.

2. Not subject to emission from other systems.

3. Does not cause any interference with itself.

EMC is concerned with the generation, transmission, and reception of electromagnetic energy. There are four aspects of EMC, which are radiated emissions, radiated susceptibility, conducted emissions, and conducted immunity. A source (also referred to as the transmitter) sends a transmission path or a transmission power association to a receiver (receiver), which is processed, resulting in desirable or undesirable behavior as shown in Figure 2.1. Interference occurs if the receiving power causes the receiver to behave undesirably [2].

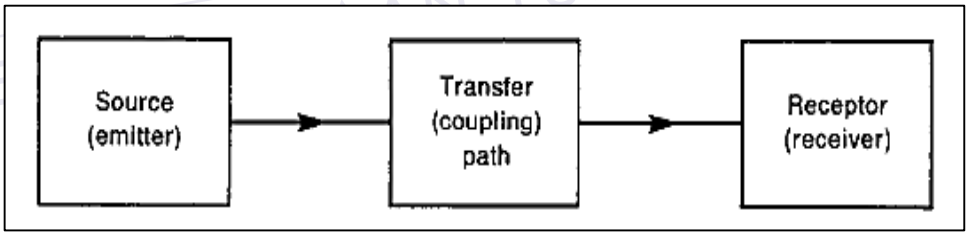

Figure 2.1: The basic decomposition of the EMC coupling problem [3]

2.2 Electromagnetic Interference

Interference is generated in a circuit or system when a benign signal of that circuit is propagated through a marginal coupling and affects another victim's circuit system, or when an improper signal is generated in the circuit and then propagated by a sound or marginal coupling and affecting the victim's circle. These signals are only interference when they affect system performance [4]. Figure 2.2 shows a diagram of

this process, sources generate interference signals during events. These signals are propagated through the system or inter-systems through appropriate paths (systems rules) or false paths (pseudo) and are received by relevant sensitive receptors. The signals received by one or a group of receivers, which exceed the system sensitivity threshold (relevant), result in failure, disturbance events[5].

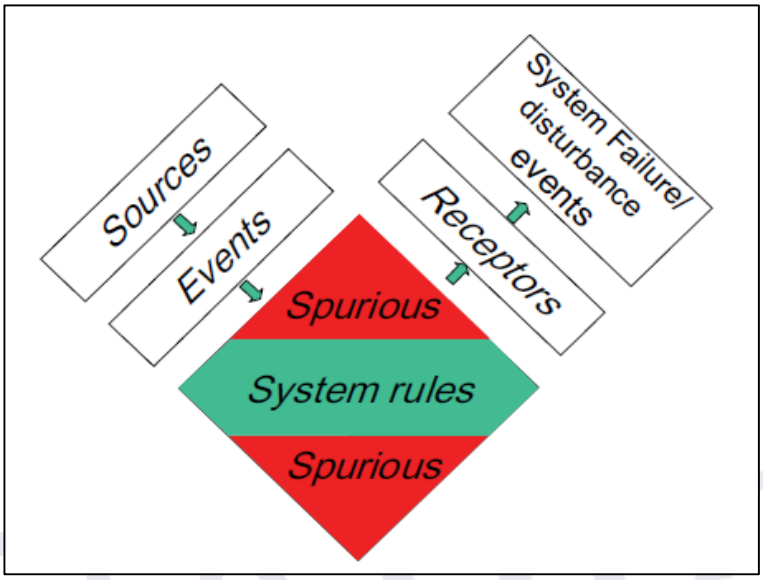

Figure 2.2: The interaction map [4]

The IEC has defined Electromagnetic Interference, EMI as [2] " Regression of the performance of a device or system by an electromagnetic disturbance".

EMI is a form of interruptions caused by an external source that affects the performance of the electric circuit through electromagnetic induction, electrical conductivity or even coupling where two or more electromagnetic waves are charged as shown in Figure 2.3 [4], [2], [5]. Radiation level generated by radiating component in a particular circuitry is required to be reduced in full measure in order to obey the EMC requirements [6].

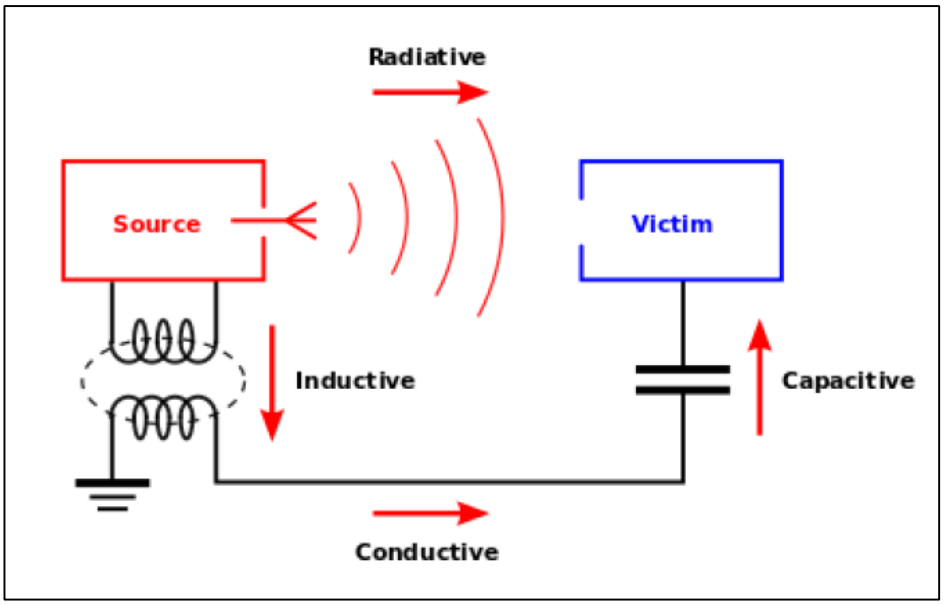

Figure 2.3: Source of electromagnetic wave [4].

Primarily, electromagnetic radiation occurs through the flow of common mode streams (CM) or differential mode (DM) in the circuit, wherein in most cases, they involve both. In general, the DM radiation is characterized by its characteristics of a current DM flow on the closed rings. It is known that the CM radiation, on the other hand, is the current that flows in the cables [6]. The rationality of previous data, the low loop area of the power or the current signal along with the tracking of each repetitive path will significantly reduce the radiation [7]. However, in this research, understanding this essential is necessary for the construction of a circuit that can generate high electromagnetic radiation for interference.

EMI has the same main aspects as EMC, which is emission and susceptibility. EMI is the interference problem and not the signal causing that problem. There are three ways to prevent interference problem [3].

1. Suppress the emission at its source.
2. Create the coupling path as incompetent as possible.
3. Make the device less liable to the emission.

2.3 Electromagnetic Compatibility Control

2.3.1 System Design and Installation

The problem can always be traced back to any circuit that is theoretically fully functioning to completely neglect the EMC standard. Troubleshooting at that very moment in order to detect the possible effect of noise causes the problem largely because it is not simple or clear for monitoring. A solution at this stage usually causes the insertion of plug-ins that is not the primary parts of the circuit to begin. These auxiliary components are added as a result of various penalties that can be realized through expenses for engineers and repeated testing. Do not forget, the cost and composition of the components of dilution along with sanctions of size, weight and energy dissipation [7], [8].

On this basis, electromagnetic (EMC) consideration should be placed primarily in the design of any digital circuit. However, the circuit design will have an opposite effect, as well as a special feature because this circuit is required to display high electromagnetic radiation in order to study the pattern and characteristics of the emitted wave. In order to obtain a circle with the prescribed qualities, the factors that cause the EMI should be understood in advance. Once understood, these factors should be emphasized as much as possible. For example, it is known that the current differential mode (DM) situation will generate high electromagnetic radiation and flows in closed rings. Logically, we can get higher radiation by expanding the closed loop of the circuit[9]. Once the outcome of this test is confirmed, the second test will be to test a different type of bonding proceeds.

2.3.2 Shielding

In order to harden integrated circuits against unintentional and intentional electromagnetic interference, and this under harsh environmental conditions, is getting more and more important to achieve the desired levels of functional performance and operational reliability despite an ever more aggressive electromagnetic environment High levels of operational reliability are increasingly being required to help control functional safety or other risks [10].

Electromagnetic shielding is the use of the shield system to the absorption, reflection and interference of interference electromagnetic wave to offset weakening energy, the high frequency magnetic field shielding is the shielding of radiation electromagnetic field [11], and also it is the procedure of limiting electromagnetic emissions through radiation by obstructive electromagnetic radiation with a shield. This shield consists of magnetic or conductive materials, usually with metal properties, one of the most famous ways of the device to protect the device against radiated electromagnetic interference it is the shielding material. Shielding material can eliminate the level of disturbance and at the same time, it does not require intervention into the electronics of the device, the most important materials used for shielding are aluminum and steel [25].

The shield acts as a separator between a device and its surroundings and even towards another device [8]. Shielding can protects the equipment from emitted highly EM as shown in Figure 2.4. In common cases, armor can be used as the electromagnetic fields of vessels that suppress the radiation.

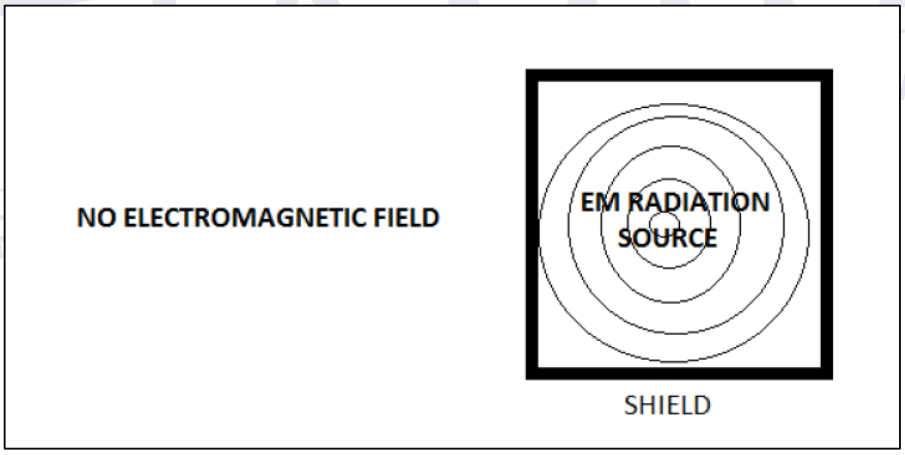

Figure 2.4: Application of shield to suppress the radiation within a specific area [8].

In other way, the equipment also is protected from surrounding. The proposed setting in Figure 2.5 provides protection for sensitive devices around the shielded area. Shielded metal traditionally used to block EMI radiation from device-to-device [12], [13].

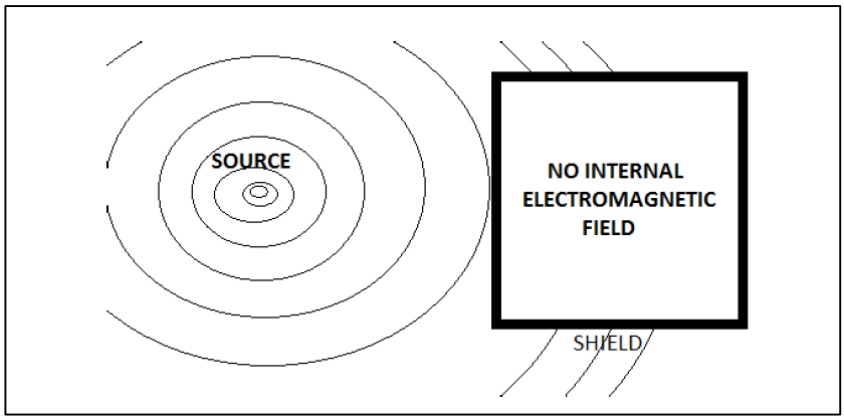

Figure 2.5: Application of shield to protect a device from external radiation [8].

In some cases, the source of electromagnetic radiation may be emitted to operate the system, such as radio stations. However, the protection of the source of electromagnetic radiation has proved to be more active than the shielding of the receptor device in a general perspective and is functional to conduct this research.

2.3.3 Grounding

In order to avoid creating EMI problems, it is necessary to realize that the effective grounding system, like any other part of the equipment or system must be carefully designed and implemented. Grounding is a problem in the system and for the grounding arrangement to perform well must be well conceived and carefully designed and implemented. Grounding configurations must be balanced in relation to dimensions and frequency, just like any functional circuit.

Theoretically, shielding is a great method to eliminate electromagnetic interference. However, since the shield itself is made of conductive material, the interaction between the electromagnetic radiations of the device inside the shield with a wall the shield produces an inductive interference [9]. Despite their small size, these are interference continues to affect the performance of adjacent devices. Attach a connector shield to the ground can help counter these complications as presented in Figure 2.6. It provides a safe path for fault currents, while also maintaining potential differences between any two points of the lowest possible installation [14].

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