STATISTICAL ANALYSIS AND FILTER DESIGN FOR CONDUCTED EMISSION NOISE

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For my wife Rosni Binti Yusoff,

My daughter and my sons,

Nur Rahwani Safwah, Muhammad Rifqi Solihin dan Muhammad Rifqi Sufi,

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ABSTRACT

Electromagnetic compatibility (EMC) is the ability of equipment and system to function as intended without degradation or malfunction in their intended operational electromagnetic environment. Further, the equipment or system should not adversely affect the operation of, or be adversely affected by any other equipment. There are two categories of Electromagnetic Compatibility; (1) Electromagnetic Susceptibility (EMS) (2) Electromagnetic Interference (EMI). EMS and EMI can be further divided into two categories namely radiated and conducted. Conducted emission is the unwanted currents that are produced by electronic and electrical equipments emitted through the power lines. The main sources of conducted emission are common mode current and differential mode current. These currents will interfere with any equipments that are connected to the same power lines. EMC standards pertaining to the conducted emission (such as EN55014) define the limit lines that should not be exceeded or the product cannot be marketed. In order to avoid non-compliance to the standards, most electronic/electrical equipments have power line filter installed into them. However, these filters are not effective enough because they were designed without considering the emission currents characteristics. This project proposed a method to improve the design of a power line filter by analyzing the characteristic of the emission current noise. The results from the statistical measurements can be used to identify the range of frequencies where most of the noises are located. Eighty four blenders were used as a sample to identify the characteristic of the noise. It was found out that the conducted emission exceed the limit line from 150kHz to 1MHz by 5dB and by 10dB at frequencies from 1MHz to 30MHz. A butterworth filter with cut-off frequency of 70.56kHz and bandwidth from 0 to 120kHz was designed. The parameters of the filter were based on the statistical data of the conducted emission. The test result shows that the filter attenuate the noise about 42dB at frequency range of 150kHz to 10MHz and 10dB at frequency range from 10MHz to 30MHz. The low attenuation at frequencies from 10MHz to 30MHz is due to the existence of capacitive and skin effect. A better filter can be achieved if a higher quality component is used in the fabrication.

ABSTRAK

Keserasian Elektromagnet (EMC) adalah kebolehan suatu sistem elektronik untuk berfungsi secara serasi dengan sistem elektronik yang lain dan ia tidak menghasilkan atau menerima interferen. Terdapat dua jenis Keserasian Elektromagnet iaitu (1) Keserasian Menerima dan (2) Keserasian Memancar. Keserasian Menerima dan Keserasian Memancar dapat dibahagikan kepada dua iaitu pengalir dan radiasi. Sinaran pengalir adalah arus yang tidak dikehendaki yang dihasilkan oleh peralatan elektrik atau elektronik melalui talian kuasa. Sumber utama pengalir dan radiasi adalah arus mod sama dan arus mod beza. Arus ini akan mengganggu peralatan yang bersambungan dengan talian kuasa yang sama. Piawaian EMC yang berhubung dengan sinaran pengalir contohnya EN55014 menyatakan peralatan elektrik yang menghasilkan sinaran melebihi aras yang ditetapkan tidak boleh dijual. Untuk mengelak dari tidak memenuhi piawaian yang ditetapkan, peralatan elektrik dan elektronik dipasangkan penapis. Walaubagaimanapun penapis ini tidak berkesan kerana ia dibina tanpa mengambil kira tentang ciri-ciri arus yang tidak dikehendaki. Projek ini mencadangkan kaedah untuk meningkatkan keberkesanan penapis dengan merujuk kepada ciri-ciri arus hingar. Keputusan dari pengukuran statistik akan digunakan untuk mengenalpasti kedudukan arus hingar. Lapan puluh empat pengisar digunakan sebagai sampel untuk memgenalpasti ciri-ciri hingar. Hingar yang melebihi aras pada frekuensi 150kHz hingga 1MHz adalah 5 dB dan 10 dB bagi frekuensi dari 1 MHz hingga 30 MHz. Penapis yang terhasil adalah butterworth dengan frequensi potong pada 70.56kHz dan lebarjalurnya ialah 0 hingga 120 MHz. Parameter penapis diambil daripada data statistik pancaran pengalir. Pengujian penapis menunjukkan pengurangan hingar 42 dB pada frekuensi 150 kHz hingga 10MHz dan 10 dB pada frekuensi dari 10MHz hingga 30MHz. Sedikit pengurangan pada frekuensi 10MHz hingga 30MHz adalah disebabkan oleh kapasitan dan kesan kulit. Penapis yang baik boleh dicapai dengan penggunaan komponen yang berkualiti tinggi dalam pembinaan.

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GLOSSARY OF ABBREVIATIONS

AC	Alternating Current
AMN	Artificial Mains Network
CE	Conducted Emission
CISPR	The International Special Committee on Radio Interference
CM	Common Mode
DC	Direct Current
DM	Differential Mode
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
EMS	Electromagnetic Susceptibility
EUT	Equipment under Test
FCC	Federal Communications Commission
HF	High Frequency
IL	Insertion Loss
ITE	Information Technology Equipment
LISN	Line Impedance Stabilization Network
N	Neutral
P	Phase
PCB	Printed Circuit Board
PDF	Probability Density Function
PFC	Power Factor Correction
RF	Radio Frequency

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CHAPTER I

INTRODUCTION

1.1 Introduction to Project

The problem of achieving electromagnetic compatibility (EMC), which is the ability of electrical equipment to coexist without mutual interference, is as old as electromagnetism itself. However the awareness of it did not arise until electromagnetic incompatibilities really become problem. As time went by, the EMC problem broadened. Not only did interference between set have to be avoided (as a result of the steadily growing density of circuit and increasingly high frequencies), it was also necessary to control electromagnetic influence of circuit within a single set, a single printed wiring board and even within a single chip. As such, it is important to create awareness and understanding on the source of emission from various circuit and their mitigation techniques.

This project will investigate the mechanism by which emission are generated and are conducted out of the product along the product's AC power cord. The conducted emission noises (electrical transient, surges and their disturbance) carried by electrical power supply line are classified into two categories, common mode current/voltage and differential mode current/voltage. EN55014 is a standard for household appliances of electrical tools and similar. This standard includes the measurement for conducted emission from frequency 150 KHz to 30 MHz [1]. Due to the proliferation of electrical and electronic product at ever increasing complexity and speed, it is desirable in the near future to look beyond 30 MHz to ensure proper mitigation device are employed such as filter. Consequently, it is of important to perform statistical study on the conducted emission noise from electrical and electronics equipments. Normally, electrical and electronic equipment that is having motor will produce high conducted noise. Most modern motor drive use varies high switching frequencies for currents and voltages, which is make unintentional current path [2]. In this project, helping certain device such as LISN, EMC Analyzer, EMTEST Software, can do measurement on class B ITE. Class B ITE is a category of apparatus which is satisfies the class B ITE disturbance limits [3]. By using a few electrical equipment as a sample for conducted emission test, can get the characteristic of noise from Gauss distribution plot. The characteristic is referring to equipment. Such as table fan, hair dyer and Blander. So that a dynamic filter can be developed which is used the characteristics of noise from measurement result. A dynamic filter can call as smart filter. This filter is applicable to filter the noise at a few equipments.

1.2 Objectives

i) To understand the mechanisms that produce conducted emission noise.

ii) To perform statistical study on conducted emission noise spectrum from electrical and electronics equipment.

iii) To design the topology for conducted emission filter based on the measurement result (ii)

1.3 Scope of Work

i) Measurement the conducted emission noise between 150 kHz to 30 MHz.

ii) To study the measurement equipments (LISN, Transient Limiter, Spectrum Analyzer and EMTEST software) function.

iii) To study the conducted emission noise (common mode and differential mode).

iv) To perform statistical analysis on conducted emission noise measurement.

v) Single phase equipment for EUT

vi) Blender was chosen for EUT

1.4 Importance of Project

i) To develop the efficiency filter which is applicable for all electrical / electronic equipment.

ii) To propose the manufacturer to use this filter.

CHAPTER II

LITERATURE REVIEW

2.1 Introduction to Electromagnetic Compatibility

Electromagnetic compatibility (EMC) is the ability of equipment and system of function as intended without degradation or malfunction in their intended operational electromagnetic environment. Further, the equipment or system should not adversely affect the operation of, or be adversely affected by any other equipment. For a system to be electromagnetically compatible, it has to generally satisfy 3 criteria which are [4]:

i. It does not cause interference with other system
ii. It is not susceptible to emission from other system.
iii. It does not cause interference with itself.

EMC is dividing into two main groups, which is the electromagnetic Interference (EMI) and electromagnetic Susceptibility (EMS). EMI is defined as a degradation of the device, equipment or system by an electromagnetic disturbance. EMS is the in ability of a device, equipment or system to perform without degradation in the presence of an electromagnetic disturbance [5]. EMI and EMS can be dividing further into two parts, which is radiated and conducted. Figure 2.1 shows the EMC network.

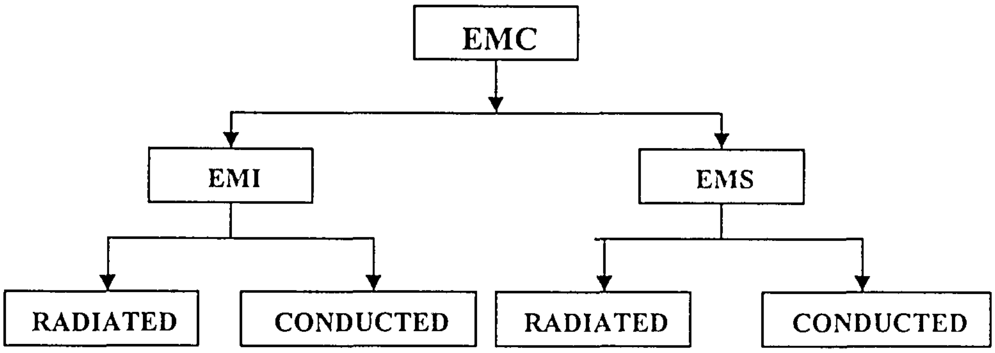

Figure 2.1: Introduction to Electromagnetic Compatibility

2.2 Introduction to Electromagnetic Interference

The undesired or unintentional coupling of electromagnetic energy from equipment (called emitter) to another equipment (called receptor) is the electromagnetic Interference [5]. The various methods of electromagnetic interferences coupling between an emitter and receptor are illustrated in figure C will briefly describe these in the following.

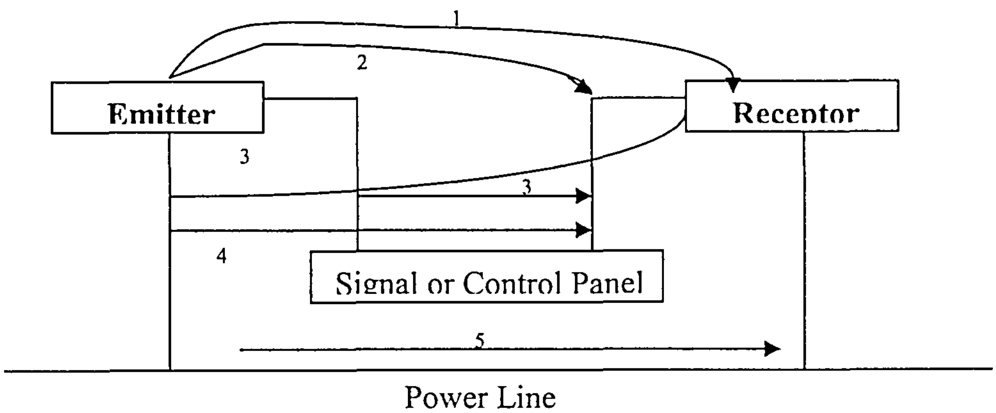

Figure 2.2: Electromagnetic Energy Coupling between Emitter and Receptor

i) Radiation from source case to receptor case and cable (1 and 2).

ii) Radiation from source cable (especially the power cable to receptor case and cables (3 and 4).

iii) Direct conduction from source to receptor via common conductor, for example, the power line.

What is conducted emission noise? The answer is noise that is produce by information technology equipment (ITE). ITE include:

i) Which has a primary function of either (or a combination of) entry, storage, display, retrieval, transmission, processing, switching, or control, of data and telecommunication messages and which may be equipped with one or more terminal ports typically operated for information transfer.

ii) With a rated supply voltage not exceeding 600v [4].

2.3 Conducted Emission Overview

Conducted emission is the emission produced by electrical equipment, which contains of some component such as motor, Scr and switch power supply. The main type of emission is divided into two types, which are the differential mode and common mode. Basically, this emission disturbed to other equipment via power line. Conducted emission occurs in range 150 kHz to 30 MHZ.

2.4 Common Mode and Differential Mode Currents

In any circuit, these are both Common Mode (CM) and Differential Mode (DM) current, both of which determine the amount of RF energy that is developed and propagated. These are a significant difference between two. Given a pair of wires or traces and return path, one or the other mode will exist, usually both. Differential Mode signals carry data or a signal of interest. Common Mode is a side effect, or a byproduct of differential mode transmission, and it is most trouble some for EMC compliance. Common Mode and Differential Mode current on line are illustrated in figure 2.3 [5].

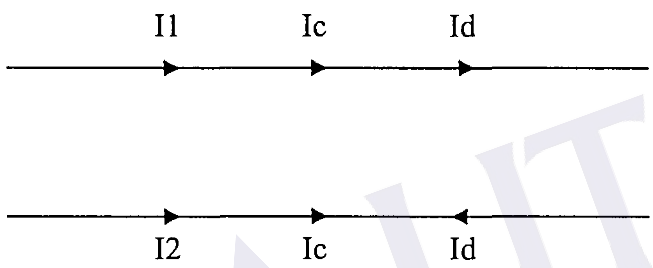

Figure 2.3: Characteristics of Common Mode and Differential Mode Current.

2.5 Equipment for Conducted Emission Measurement

A measurement result is only complete when accompanied by a quantitative statement on the measurement uncertainty. In conducted emission measurement, a few equipments should be used, which are Line impedance stabilization network, transient limiter, spectrum analyzer and personal computer.

2.5.1 Line Impedance Stabilization Network

Information technology equipment market for consumer, commercial, or military use must first meet conducted noise limit that are specified in term of voltage measured at Line Impedance Stabilization Network (LISN) test port [5]. There are the objectives to use the LISN.

i. To prevent a constant impedance to the product's power cord outlet over the frequency range of the conducted emission test.
ii. To block conducted emission that are not due to the product being tasted so that only the conducted emission of the product are measure.

LISN is quite similar with Artificial Main Network (AMN). AMN is required to provide defined impedance at high frequencies across the power feed at the point of measurement of terminal voltages, and also to provide isolation of the circuit under test from ambient noise [4]. These two objectives are to be satisfied only over the frequency range of the conducted emission test (450 kHz – 30 MHz for FCC measurement and 150 kHz to 30 MHz for CISPR 22 measurement). Another subtle but unstated requirement for the LISN is that it be able to pass the 60 Hz / 50 Hz power required for operation product.

LISN is one of the devices for separation of the common mode and differential mode noise. The basic separation of CM and DM current is shown in figure 2.4. This scheme represents the equivalent circuit of a LISN in the high frequency behavior and the equipment under test is shown as electromagnetic noise source [6]. The LISN specified for use in the FCC conducted emission measurement is shown in figure 2.4.

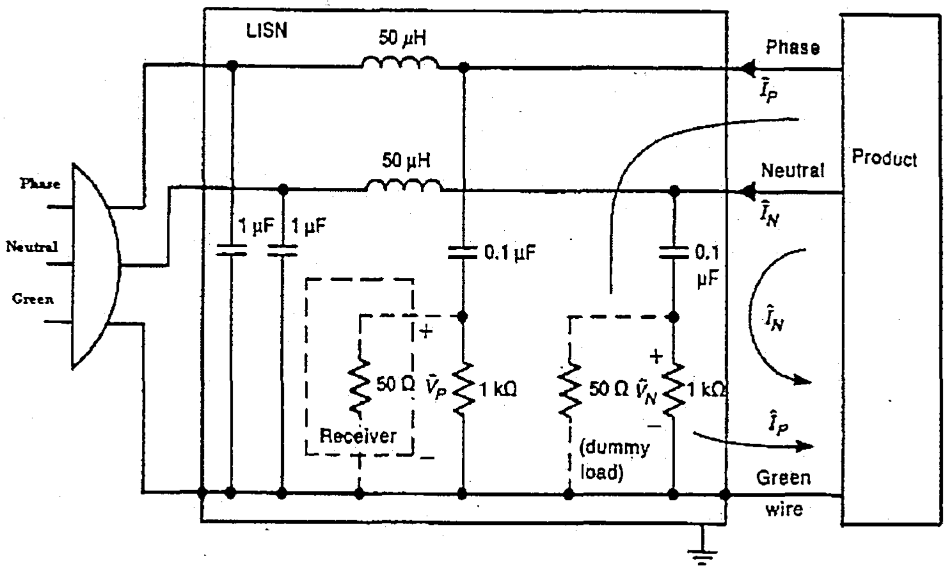

Figure 2.4: Illustration of the LISN Circuit.

While LISN are normally used in EMC compliance laboratories, current probes are more convenience and normally used in field surveys [5]. The purpose of the 1µF capacitor between Phase and Green wire and between Neutral and Green wire on the commercial power side is to divert "external noise" on the commercial power net and prevent that noise from flowing through the measurement device and contaminating the test data. Similarly, the purpose of the 50µH inductors is to prevent any DC from overloading the input of the test receiver.

To appreciate the constraints on fully compliant conducted tests you have to be familiar with the test equivalent circuit (figure 2.5). This shows that in the main port test you are measuring a combination of DM and CM source on each line (P or N) with respect to the ground [5].

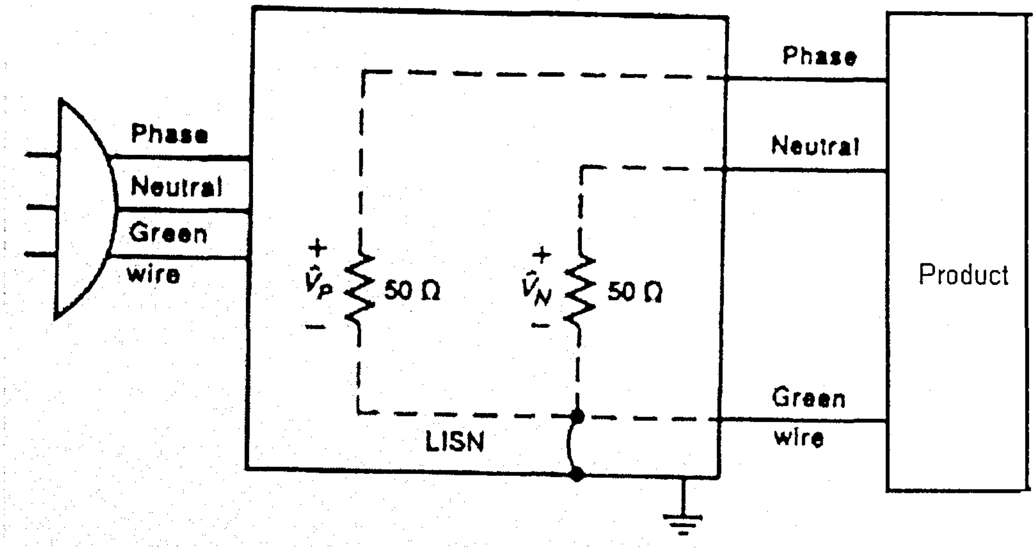

Figure 2.5: Equivalent Circuit of the LISN as seen by Product over is intended Frequency range of use.

It is instructive to compute the impedances of these elements at the lower frequency limit, 450 kHz, and the upper frequency limit, 30 MHz, of the FCC regulatory limit. These are thus the capacitors are essentially short circuit over the measurement frequency range, and the inductor present large impedance. The 1 kΩ resistors act as static charge paths to discharge the 0.1μF capacitors in the event that the 50Ω resistors are removed. Resistances of 50Ω are placed in parallel with these I K resistors become disconnected [5]. One 50Ω resistor is the input impedance of the these receiver (spectrum analyzer), while the other is a 50Ω dummy load that insures that the impedance between Phase and the safety wire and between Neutral and safety wire is approximately 50Ω at all times. The measured voltages, denoted by V_p and V_n, are measured between the Phase wire and the safety wire and between the Neutral wire and the safety wire. Both the phase and the neutral voltages must be measured over the frequency range of the conducted emission limit, and must be below the specified limit at every frequency in the limit frequency range [5]. Now we see why the conducted emission limits are specified in term of voltages when, in fact, we are interested in conducted emission currents. The Phase current Ip and the Neutral current, In are related to the measured voltages by

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