EXPERIMENTAL INVESTIGATION OF ELECTROMAGNETIC INTERFERENCE SHIELDING EFFECTIVENESS OF CONCRETE BLOCK INCORPORATED WITH CARBON FIBER AND CARBON NANOTUBE

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ABSTRACT

High conducting metal such as Mu-metal, aluminum and silver are commonly used as shielding material which prevents electromagnetic radiation by reflection. However, metal material exhibit various disadvantages such as heavy weight, high cost, poor corrosion resistance and poor processing. Over these few decades, non-metal materials such as carbon black (CB), carbon fiber (CF) and carbon nanotube (CNT) are gaining popularity as they are corrosion resistant, have high tensile strength, are light weight, have low cost and design flexibility. The use of EMI shielding in commercial and military application has rapidly increased and are widely used. Therefore, the objective of this study is to investigate the EMI shielding effectiveness (SE) of non-metal materials used in concrete block via experimental methods. There are two materials used in the study, namely carbon fiber and multi-walled carbon nanotube (MWCNT). The EMI SE of carbon fiber was studied with respect to their orientation at the same layer of material while MWCNT was examined by different weightage percentage. The EMI SE measurement was conducted using Vector Network Analyzer (VNA) in the frequency range of 2.4 GHz to 4.2 GHz. The results show that CF sample with perpendicularly orientation of CF (0^0/90^0/ 0^0/ 90^0/ 0^0) has higher EMI SE than other CF samples with EMI SE of -40.26 dB at 4.02 GHz with improvement of 15.71 % compared to reference

sample. Meanwhile, it is found that CNT sample with 2.0 wt% of MWCNT has higher EMI SE compared to the sample with 1.5 wt% and 1.8 wt% of MWCNT. This sample obtained the highest EMI SE of -40.78 dB at 3.45 GHz with improvement of 17.23% compared to reference sample. The compressive strength test of concrete block was also conducted using compressive strength machine. It was observed that, all concrete blocks passed the strength test according to the grade 30 concrete mixture standard that is adjudged to be safe for application in building construction.

ABSTRAK

Pengalir tinggi logam seperti logam-Mu, aluminium dan perak biasa digunakan sebagai bahan yang menghalang sinaran elektromagnet melalui mekanisma pemantulan. Walau bagaimanapun, bahan-bahan logam ini mempunyai pelbagai kelemahan seperti kos yang tinggi, berat, ketahanan hakisan yang lemah dan sukar untuk diproses. Sejak beberapa dekad, bahan bukan logam seperti *carbon black* (CB), *carbon fiber* (CF) dan *carbon nanotube* (CNT) semakin popular kerana ia tahan hakisan, mempunyai kekuatan tegangan yang tinggi, ringan, kos rendah dan mudah dibentuk. Penggunaan perisai EMI dalam aplikasi komersial dan tentera telah semakin meningkat dan digunakan secara meluas. Oleh itu, objektif kajian ini adalah menganalisis keberkesanan perisai EMI bahan-bahan bukan logam yang digunakan dalam blok konkrit. Terdapat dua bahan-bahan yang digunakan dalam kajian ini iaitu *carbon fiber* dan *multi-walled carbon nanotube* (MWCNT). Keberkesanan perisai EMI *carbon fiber* diuji mengikut orientasi yang berbeza dengan menggunakan lapisan yang sama bahan manakala MWCNT diuji mengikut kepekatan yang berbeza. Keberkesanan perisai EMI ini diuji menggunakan *Vector Network Analyzer* (VNA) dalam julat frekuensi 2.4 GHz hingga 4.2 GHz. Hasil kajian menunjukkan bahawa sampel CF yang berorientasikan tegak lurus daripada CF (0^0 / 90^0 / 0^0 / 90^0 / 0^0) mempunyai keberkesanan

perisai EMI lebih tinggi berbanding sampel CF yang lain dengan nilai -40.26 dB pada frekuensi 4.02 GHz dengan peningkatan sebanyak 15.71% berbanding dengan sampel rujukan. Sementara itu, didapati bahawa sampel CNT dengan kepekatan MWCNT sebanyak 2.0% mempunyai keberkesanan perisai EMI yang lebih tinggi berbanding sampel yang memiliki kepekatan 1.5% dan 1.8% daripada MWCNT. Sampel ini memperoleh keberkesanan perisai EMI yang tertinggi dengan -40.78 dB pada frekuensi 3.45 GHz dengan peningkatan 17.23% berbanding dengan sampel rujukan. Ujian kekuatan mampatan konkrit juga dijalankan menggunakan mesin kekuatan mampatan. Diperhatikan bahawa kesemua blok konkrit lulus ujian kekuatan mengikut piawaian konkrit iaitu gred 30 di mana selamat untuk digunakan dalam pembinaan bangunan.

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APPROVAL

This thesis was submitted to the Senate of Universiti Pertahanan Nasional Malaysia and accepted as partial fulfillment of the requirement for the degree of Master of Science (Electrical and Electronics Engineering). The members of the Supervisory Committee were as follows:

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APPROVAL

I certify that an Examination Committee has met on 18th May 2017 to conduct the final examination of Mahadi bin Sharif on his degree thesis entitled 'Experimental Investigation of Electromagnetic Interference Shielding Effectiveness of Concrete Block Incorporated with Carbon Fiber and Carbon Nanotube'. The committee recommends that the student be awarded the Master of Science (Electrical and Electronics Engineering).

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS AND SYMBOLS

EMI	-	Electromagnetic Interferences
EM	-	Electromagnetic
CF	-	Carbon Fiber
CNT	-	Carbon Nanotube
EMC	-	Electromagnetic Compatibility
STRIDE	-	Science And Technology Research Institute of Defence
CB	-	Carbon Black
SE	-	Shielding Effectiveness
MWCNT	-	Multi-Walled Carbon Nanotube
VNA	-	Vector Network Analyzer
WLAN	-	Wireless Local Area Network
LTE	-	Long Term Evolution
S-Parameter	-	Scattering-Parameter
SUT	-	Sample Under Test
dB	-	Decibel
CISPR	-	Comité International Spécial des Perturbations Radioélectriques
RF	-	Radio Frequency
P_i	-	Incident Power
P_t	-	Outgoing Power
NR	-	Natural Rubber
EVA	-	Ethylene Vinyl Acetate
SFC	-	Short Carbon Fiber
SF	-	Silica Fume
HDPE	-	High-Density Polyethylene
GA	-	Gum Arabic
DW	-	Distilled Water
OPC	-	Ordinary Portland Cement

BS	-	British Standard
UPNM	-	Universiti Pertahanan Nasional Malaysia
SAC	-	Semi Anechoic Chamber
UHF	-	Ultra High Frequency
PVP	-	Polyvinylpyrrolidone
HCTAB	-	Hexadodecyltrimethylammoniumbromide
R	-	Reflectance
T	-	Transmittance
A	-	Absorbance
P	-	Pressure
F	-	Force
A	-	Area
Hz	-	Hertz
cm	-	Centimeter
wt%	-	Weightage Percentage
N/mm^2	-	Newton Per Meter Square
N	-	Newton
m^2	-	Meter Square
MPa	-	Megapascals
CS	-	Compressive Strength

CHAPTER 1

INTRODUCTION

1.1 Background

The electromagnetic interference (EMI) is an electromagnetic (EM) signal that unintentionally disturbs and influences the operation of electronics devices. The devices are affected by these unwanted signals either via radiation, conduction or emission which can interfere and degrade electronics system performance of certain devices or equipment such as computer, radio, mobile communication, medical and military systems [1, 2]**.** The rapid development of electronic systems and telecommunication technologies causes the EM pollution continues increasing to a level never attained before [3]**.**

The influence of EM signals have drawn huge attention since few decades ago as there were a lot of occurring accidents related to EMI such as aircraft crash, uncommand missile signal launch, and

interruption of medical equipment [4]**.** One serious case of EMI occurred on the USS Forestall and reported number of 134 people were killed and caused a damage of $ 72M [5].

The implementation of some techniques such as Spread Spectrum analysis, EMI filters and shielding have been developed which are able to reduce the EM radiation [6]. The spread spectrum analysis is a technique used to modulate the EMI signal and spread the energy over a wider frequency range by applying square wave signals while the EMI filter is a technique where the combination of capacitors and inductors as the filter to eliminate the unwanted frequency signal from entering the system. However, the EMI filter is not only for eliminating the noise, but also for preventing the creation of noise by the system.

EM radiation shielding technique is one of the most common technique which provide effective and excellent shielding properties in order to reduce and limit the EM wave radiation. The technique is implemented using appropriate shielding material in order to prevent the EMI penetration.

In this project, the shielding efficiency of carbon fiber (CF) and carbon nanotube (CNT) in term of shielding in cement composites with respect to their orientations and weight percentages were investigated. The materials are placed inside the concrete block and measured in the frequency range from 2.4 GHz to 4.2 GHz. The EMI penetration test is

conducted in the electromagnetic compatibility (EMC) semi-anechoic chamber at Science and Technology Research Institute of Defence (STRIDE).

1.2 Problem Statement

The EMI problem is commonly reduced by shielding the electromagnetic signal. The most effective EMI shielding materials have high conductivity, high permittivity and high aspect ratio [7]. Therefore, the attenuation of EMI has been recently investigated by many researchers [8 – 12].

Metal-based materials can be classified as the most effective shielding materials for reducing EMI. Different kinds of metals such as Mu-metal, aluminum and copper are widely used in commercial and industrial applications. High conducting materials such as metals were used as shielding material; preventing electromagnetic radiation makes it a very good candidate for EMI shielding. However, metal exhibit various disadvantages such as heaviness, cost, corrosion, poor processing, molding properties and processability [13].

Compared to metal based EMI shielding materials, carbon based composites such as carbon black (CB), CF and CNT have gained particular interest due to their light weight, versatility, corrosion resistance, flexibility and processing advantages [14 – 16]. In addition, both CF and CNT possess high conductivity, high permittivity, small

diameter and high aspect ratio [17, 18] which exhibit higher EMI shielding effectiveness (SE). CNTs have been considered as a promising candidate which having excellent electrical conductivity and unique length-to-diameter ratio [19].

1.3 Objective of the Study

Two materials are used in the project, namely carbon fiber and multi-walled carbon nanotube (MWCNT). The objective of this study as follow:

1. To investigate the EMI shielding effectiveness (SE) of non-metal materials used in the concrete block experimentally.
2. To analyze the EMI SE performance as well as the comparison for both CF and CNT samples.

1.4 Scope of the Study

i. Conducting literature review on the EMI, EMI shielding material as well as shielding effectiveness.

ii. Preparation of EMI shielding materials.

iii. Investigation of EMI SE of concrete block incorporated with carbon fiber and carbon nanotube experimentally.

iv. Analyzing and interpreting results of EMI SE performance as well as the comparison for both CF and CNT samples.

1.5 Contribution of the Study

The drastic increase in EMI-related problems nowadays causes the existing EMI shielding techniques seem to be less effective. Therefore, there is a need to develop an EMI shielding to reduce EMI pollutions as well as improve the reliability and capability of system. In this study, EMI SE of CF and MWCNT were investigated in the frequency range of 2.4 GHz to 4.2 GHz as factors affecting the EMI SE such as concentration and orientation of material were taken into consideration. As a result, the development of EMI shielding in concrete block incorporated with CF and MWCNT will able to reduce EMI signal penetration in many application such as Wireless Local Area Network (WLAN), Bluetooth, microwave oven and medical devices (2.4 GHz to 2.5 GHz); amateur radio and commercial Long Term Evolution (LTE) devices (3.4 GHz to 3.6 GHz); and moderate range surveillance and weather radar (2 GHz to 4 GHz).

1.6. Outline of the Study

This study comprises of five chapters. Chapter 1 begins with the background, problem statement, objectives of the study, scope of the study, contribution of the study and outline of the study. Chapter 2 presents an overview of the literature review related to EMI shielding material researches and its connection to this study. Next, Chapter 3 elaborates on the research methodology used in conducting the

experiments. Chapter 4 discusses the results obtained from EMI SE of CF and MWCNT based EMI shielding. Finally, Chapter 5 concludes the overall findings and recommendations for the future studies.