# A NEW MULTI-LAYERED MICROWAVE ABSORBER FOR WIRELESS APPLIANCE USING COCONUT SHELL-BASED MICROWAVE ABSORBERS

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# 1. Letter of Report Submission

| BAHAGIAN A : MAKLUMAT KETUA PROJEK | |
|---|---|
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| Alamat Pusat Tanggung Jawab (PTJ) | Microwave Technology Center (MTC), Fakulti Kejuruteraan Elektrik, Universiti Teknologi MARA |
| Tajuk Projek: | **:** A New Multi-Layered Microwave Absorber For Wireless Appliance Using Coconut Shell-Based Microwave Absorbers |
| **BAHAGIAN B : MAKLUMAT PROJEK PENYELIDIKAN** | |
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| **BAHAGIAN C : HASIL PENYELIDIKAN** | |
| **Penerbitan Berindeks**<br>(Tajuk dan Penerbit) | [1] Salleh, M. K M; Yahya, M.; Awang, Z.; Muhamad, W. N W; Mozi, A.M.; Yaacob, N., "Binomial multi-layer coconut shell-based rubber microwave absorber design," *RF and Microwave Conference (RFM), 2011 IEEE International* , vol., no., pp.187,190, 12-14 Dec. 2011<br>[2] Salleh, M. K M; Yahya, M.; Awang, Z.; Muhamad, W. N W; Mozi, A.M.; Yaacob, N., "Single layer coconut shell-based microwave absorbers," *TENCON 2011 - 2011 IEEE Region 10 Conference ,* vol., no., pp.1110,1113, 21-24 Nov. 2011<br>[3] Salleh, M. K M; Yahya, M.; Awang, Z.; Muhamad, W. N W; Mozi, A.M.; Yaacob, N., "Experimental verification of multi-layer coconut shell-derived microwave absorbers," *RF and Microwave Conference (RFM), 2011 IEEE International* , vol., no., pp.115,118, 12-14 Dec. 2011<br>[4] Mohd Kamarulzamin, Mazlaini Yahya, Zaiki Awang, "Coconut Shell-Based Microwave Absorbers," *Indonesia-Malaysia Microw. Antenna Conf.*, Jakarta, Indonesia, 11-12 Jun. 2010.<br>i) Awards/ Others<br>Best Student Paper Award: Third Place in Indonesia-Malaysia Microwave Antenna Conference, 11-12 June 2010. |
| **Harta Intelek**<br>(No Patent/No IP) | - |
| **Pelajar yang di latih**<br>(Nama, KP, Kod Program) | Nama : Mohd Kamarulzamin bin Salleh<br>KP : 820717-11-5061<br>Kod program : EE780 |
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## 4. Enhanced Research Title and Objectives

Original Title as Proposed:

A new multi-layered microwave absorber for wireless appliance using coconut shell-based microwave absorber coatings

Improved/Enhanced Title:

A new multi-layered microwave absorber for wireless appliance using coconut shell-based microwave absorber

Original Objectives as Proposed:

1. To investigate the physical and microwave properties of a microwave absorber by modifying carbon concentration content from coconut shell inside an epoxy resin matrix
2. To study transmission and reflection properties of single and multi-layer microwave absorbers by optimizing layer thickness and carbon content for each layer
3. To investigate the absorber shielding efficiency in combating radio frequency interference in real WLAN applications

Improved/Enhanced Objectives:

1. To characterize the microwave properties of absorbers made of different carbon concentrations.
2. To design single and multi-layer absorbers using electromagnetic simulation.
3. To develop and study single and multi-layer absorbers using coconut shell-based as absorbing material.

# 5. Report

## 5.1 Proposed Executive Summary

Wireless Local Area Network (WLAN) systems operate in the 2.4 GHz ISM unlicensed band that is prone to interferences which can severely affect performance. This research aims to demonstrate the possibility of using coconut shell-based activated carbon as a microwave absorbing material to mitigate radio frequency interference. The absorber will be prepared in the form of coatings which can be conveniently applied to the panels of high frequency equipment which will act as a shield to reduce electromagnetic interference.

An industry standard, full three-dimensional electromagnetic simulator will be used to predict the microwave behaviour of single and composite coatings of varying thickness and relative permittivity. Both air and metal-backed coatings will be simulated, and optimal material parameters will be determined from the simulations for use in sample fabrication. The samples will then be characterized using a free-space microwave non-destructive test set-up to determine the reflection and absorption characteristics of the coatings. From the measurement, optimum values of coating thickness and coconut shell content for specific application will be determined. We hypothesize that coconut shell as a locally-sourced material can be shown to act as an alternative filler for microwave absorbers to protect high frequency equipment against unwanted co-channel interferences from other radio frequency sources. This proposal will also add value to a locally sourced material in the production of advanced materials

### 5.2 Enhanced Executive Summary

Microwave absorbers are used for reducing radar detection and overcome the wireless interferences. Carbon is a one of main component in microwave absorbers. Coconut shell activated carbon was used in this project which one type of carbon. Coconut shell powder was mixed with Flaxane-80 as binder in producing microwave absorber samples. Different percentages of carbon content samples were prepared to study the microwave properties. The permittivity of samples increases when the carbon content increases. The single layer absorbers also produced with various of thicknesses. The resonant frequency of single layer absorber goes to lower value when the thickness increases. The single layer exhibits narrow bandwidth characteristic. The two, three and four layer microwave absorber samples were fabricated. The bandwidth of multi-layer absorbers increases when number layer was added.

## 5.3 Introduction

The RF interferences come from many different radio sources namely Bluetooth applications, bar code scanners, DECT phones, hand-held palm computers, car alarms and microwave ovens which occupy the same frequency band. These radio sources are the main WLAN interference sources apart from co-channel interferences from other WLAN applications [2-5]. The WLAN protocol allows each station to transmit packets only when channel is free. Interference occurs when sufficient interference signal strength appears as fake 802.11 transmission signal forcing the intended WLAN application to back-off until the channel is clear.

IEEE 802.15 Working Group reported that interference sources can cause severe throughput performance on WLAN applications [6]. In order to combat electromagnetic interference, Radar Absorbing Material (RAM) is used to enhance the shielding performance against unwanted co-channel interferences from non-intended RF sources. RAM is a non-conductive material that is mixed with conducting fillers such as carbon, metal flake and fibers [7].

Non-conductive material is used for bonding the conducting fillers together. The conductivity of the absorber is provided by absorbing filler such as carbon black, carbon nanotube, carbon fibers and activated carbon that has imperfect conductivity. Coconut shell is one of carbonaceous material used in commercial activated carbon production due to its excellent micro-structure and low ash content [8]. Activated carbon is an amorphous solid made up mostly of carbon and small percentages of ash, water vapor and volatile matters. It is prepared using phosphoric acid in chemical activation or by physical activation in $CO_2$ and steam.

## 5.4 Brief Literature Review

High loss or lossy materials attenuate microwave that pass through them. This is usually demonstrated by refraction index, relative permittivity, or relative permeability, which are all complex number [1].The losses in this circumstances caused by the imaginary component. In reality, the loss is actually a conversion of incoming energy into heat, causing the reflected energy to be decreasing.

Matrix and filler are two basic components of microwave absorber. The matrix is the foundation material or the body for the absorber, while the filler is the working material in absorption of microwave. Beside matrix and filler, spacers are also known to be part of certain microwave absorber, with the application of styrofoam, polyurethane foams, polyesters, plywood, and honeycomb structure [2].

Elastomers have been used extensively with carbon in the manufacturing of elastomeric microwave absorber. Natural rubber is one of the most applied elastomer in fabricating microwave and radar absorber. It can have a better environment resistance over the foam-type microwave or radar absorbers. Rubber was used by Srivastana [3], in introducing absorber sample formed by using rubber as the matrix, followed by fillers of carbon and ferrite. The three elements were combined in a certain ratio, by mixing and later turned into mould, where it was pressed into plate in a hydraulic pressure system. Resin is also used widely as absorber matrixes beside elastomer. The ease in microwave and radar absorber fabrication makes it the excellent choice. Epoxy, polyester, bismaleide and polyamide resin have been used widely with absorbing material such as carbon, graphite and ferrite.

Fillers are the element that usually improves the required design of the microwave absorber. They may contribute to its conductivity, absorption and even strength and other properties. [4]. Typical fillers for microwave absorbers are graphite, carbon, iron, aluminum flakes and ferrites.

Ferrites are ceramic-like ferro magnetic materials, which mainly compose of ferrite oxide. Their applicability in reducing television ghosting, echoes from ship's radar signals and electromagnetic wave leakage increase their demand in EMC research. Various types of soft ferrites such as Cu-Zn, Mn-Zn, Ni-Zn and other substituted soft ferrites are being used as materials for ferrite-based absorber [5]. In Japan, big company such as TDK and Tokin are very strong in ferrite technology, with concentration on radiation absorber and microwave oven door shielding. TDK itself have sold more than 40 of ferrite-based Anechoic Chamber to solve electromagnetic problem in 1989 [6].

Carbon is widely used as filler in elastomers, plastics and paints to modify mechanical, electrical and optical properties. Carbon with distinctive electrical properties had received special attention in the polymer industry and as to the manufacture of conductive polymer compound. It was also the only non-metallic conductor, beside semiconductor, which is used widely in electronic application. The physical properties of carbon such as high surface area can be utilized in the preparation of heterogeneous metal catalysts because of its stability in various chemical environments [7]. The surface area of carbon also helps in providing significant ohmic conductivity, while behaving as high resistance metal at the same time. This resistance characteristic makes it possible to become dissipative element in microwave absorber.

The working principles of each absorber determine the design of microwave absorber. It was based on the nature of its usage, whether for indoor academic studies or for outdoor field application. Neelakanta had classified microwave absorber based on applications, materials, forms, bandwidth and frequency of operation [8]. Vinoy and Jha had concluded that microwave absorber could be specified within operational bandwidth condition, such as narrowband or broadband condition [9].

The simplest form of microwave absorber is the single layer resonant absorber such as Salisbury screen and Dallenbach layer. In the Salisbury screen design, a layer of resistive material is separated from metal backing reflector by a spacer made from styrofoam or honeycomb structure with a thickness of *d.* The resistive layer can be a lossy resin plus porous graphite- impregnated or carbon-loaded sheet that is positioned a quarter wavelength in front of the metal backing reflector. The resistive layer works on phase cancellation of incident energy that is reflected through the material by back metallic plate. The two waves destructively interfere with each other thus resulting in continuous cancellation. It undergoes multiple internal reflections to give rise to a series of emergent wave, thus creating a zero reflecting condition [9]. The Salisbury screen can work as perfect absorber in normal in incidence (with no reflection) when the resistance of resistive layer is as same as free space (377 ohm/sq) and the spacer thickness is an odd multiple of the quarter wavelength as: [1]

The reflectivity of Salisbury screen increases for non-normal incidences, with typical reflectivity for such incidences is usually below –20dB from off normal angles up to $35^{o}$. The simplicity of single layer absorber such as Salisbury screen comes with the disadvantages of being narrowband nature. However, the screen can be upgraded into more effective multilayers absorber using various optimisation techniques [10][11].

The multilayer microwave absorbing panel was constructed based on the principles of graded absorber [1]. The operating bandwidth can be extended from narrowband condition to a broader bandwidth by applying two or more layers into the microwave absorber design. Recent development of multilayers absorber involved various improvements technique by using numerical optimizations [12].

Perini and Cohen [13] developed a Powell method to design radar-absorbing materials (RAM) consisting of several dielectric layers. The absorption of RF energy was mostly done in the last layer, and the others were used to match the wave impedance of the RAM to that of the incidence medium. A two-layer absorber composed of the mixture of iron particles and rubber as the inner layer, and of barium hexaferrite powder and rubber as the outer layer, has better attenuation properties compared with the one-layer structure. The reflection of the incident wave can be reduced with increasing matching of the impedance of the outer layer and of free air, while the inner layer can ensure that the microwave power may be mostly exhausted [14]. Meshram reported a two-layer absorber which can provide higher absorption of the order of –9 dB from 8.7 to 10.2 GHz as compared to a single-layer microwave absorber [15].

Modern shields and electromagnetic wave absorbing structures employ different kind of materials from simplest metallic shields to complex composite structures or conductive polymers. Since absorption of electromagnetic energy happens due to magnetic, dielectric and conductive loss the shielding properties are defined by complex dielectric constant, magnetic permeability and conductivity of material that has to be maximized for maximum shielding efficiency. Reflection of radio waves occurs at any non uniformity in material and interfaces while reflection coefficient is proportional to difference between wave resistance of free space and shield material.