# RF SHIELDED HAT TO PROTECT CAMERAMAN FROM WIRELESS VIDEO-CAMERA EXPOSURE

by



**Nurbaizatul Binti Badrul Hisham**
**(1430811340)**

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## LIST OF ABBREVIATIONS

| | |
|---|---|
| ANOVA | Analysis of Variance |
| ANSI | American National Standards Institute |
| BMI | Body Mass Index |
| BT | Body Temperature |
| CANTAB | Computer-administered Cambridge Neurophysiological Test Automated Battery |
| DIA | Diastolic blood pressure |
| EME | Electromagnetic Energy |
| EMF | Electromagnetic Field |
| HR | Heart Rate |
| ICNIRP | International Commission Non-Ionizing Radiation Protection |
| IEEE | Institute of Electrical and Electronics Engineers |
| IEEE-SA | Institute of Electrical and Electronics Engineers – Standards Association |
| IEEE-USA | Institute of Electrical and Electronics Engineers – United States |
| NASA | National Aeronautics and Space Administration |
| PAL | Paired Associated Learning |
| PC | Personal Computer |
| RF | Radio Frequency |
| RF EMF | Radio Frequency Electromagnetic Field |
| RTI | Reaction Time |
| RVP | Rapid Visual Processing |
| SE | Standard Error |
| SSP | Spatial Span |

| | |
|---|---|
| SYS | Systolic blood pressure |
| WHO | World Health Organizations |
| Wi-Fi | Wireless Fidelity |

## LIST OF SYMBOLS

| | |
|---|---|
| cm | Centimetre |
| Hz | Hertz |
| kg | kilogram |
| m | meter |
| $m^3$ | cubic meter |
| min | minute |
| *M* | Mean Length |
| MHz | Mega Hertz |
| GHz | Giga Hertz |
| W | Watt |

**Topi Pelindung Frekuensi Radio bagi Melindungi Jurukamera daripada Pendedahan Kamera Video tanpa Wayar**

## ABSTRAK

Kebelakangan ini, pengguna sentiasa terdedah kepada medan elektromagnet (EMF) dalam kehidupan seharian termasuklah kegunaan harian seperti telefon bimbit, komputer, peti sejuk dan ketuhar gelombang mikro. Telefon bimbit terutamanya, apabila sedang beroperasi, antena penghantar berada sangat dekat dengan kepala pengguna dan ia menimbulkan persoalan sama ada pengguna yang menggunakannya boleh terdedah kepada tahap berbahaya sinaran elektromagnet. Pada masa kini, disebabkan perkembangan pantas teknologi komunikasi tanpa wayar, peningkatkan jumlah pekerjaan telah beralih kepada penggunaan alatan tanpa wayar. Oleh itu, jurukamera yang terdedah kepada pancaran EMF yang disebabkan oleh Kamera Video tanpa wayar telah meningkatkan kesan risiko kesihatan terhadap mereka. Tesis ini akan memberi tumpuan kepada kesan Kamera Video tanpa wayar kepada jurukamera dengan memakai topi pelindung RF yang dapat melindungi mereka daripada pendedahan EMF. Tujuan penyelidikan ini adalah untuk menambah lapisan baru pelindung bagi topi pelindung RF yang boleh melindungi jurukamera daripada pendedahan EMF. Projek ini memfokuskan topi yang biasa yang boleh dilaraskan saiz dan selesa. Topi ini dijahit dengan lapisan penyerap gelombang mikro yang bertindak sebagai pelindung daripada RF-EMF. Kesan pendedahan RF-EMF pada jurukamera dikaji dengan menggunakan prestasi kognitif, kesejahteraan, persepsi kepad EMF dan parameter fisiologi. Kajian ini bertujuan untuk menguji sama ada pendedahan daripada Kamera Video tanpa wayar boleh menjejaskan prestasi kognitif, kesejahteraan, persepsi terhadap EMF dan parameter fisiologi pada jurukamera dan sama ada topi pelindung RF yang dipakai oleh jurukamera boleh mengurangkan kesan pendedahan kepada RF-EMF. Dua jenis keadaan pendedahan dipertimbangkan: sham (tiada pendedahan) dan pendedahan Kamera Video tanpa wayar dan dua puluh mata orang subjek yang sihat terlibat dalam eksperimen ini. Keputusan analisis dua-hala Anova mendedahkan bahawa tiada perbezaan analisis yang ketara ($P > 0.05$) antara memakai dengan tidak memakai topi pelindung RF dan juga antara dua isyarat (Sham dan Kamera Video tanpa wayar) kecuali jumlah ralat PAL (diselaraskan) dan ujian RVP. Semasa pendedahan kamera video tanpa wayar dengan topi pelindung RF dalam gejala subjektif kesejahteraan, tidak terdapat perbezaan yang ketara ($P > 0.05$) antara Sham dan pendedahan aktif dalam apa jua gejala subjektif, dan ini jelas menunjukkan bahawa tidak ada tanda-tanda yang dialami berkait dengan pendedahan Kamera Video tanpa wayar. Siasatan dilanjutkan lagi untuk menyiasat persepsi subjek terhadap EMF. Majoriti subjek merasakan bahawa mereka boleh merasa radiasi RF-EMF dalam kedua-dua pendedahan (Sham dan Kamera Video tanpa wayar). Keputusan menunjukkan untuk parameter fisiologi dengan topi pelindung RF diantara pendedahan Sham dan isyarat Kamera Video tanpa wayar, tidak ada perbezaan yang ketara ($P>0.05$) untuk semua parameter fisiologi kecuali untuk tekanan darah sistolik ($P<0.05$). Kajian ini telah membawa kepada kefahaman tentang kesan pendedahan mengenai neurophysiological dan tingkah laku subjek.

**RF Shielded Hat for Protecting Cameraman from Wireless Video-Camera Exposure**

## ABSTRACT

Recently, people always exposed to electromagnetic field (EMF) in their everyday life including in daily use such as mobile phone, computers, refrigerators and microwave oven. Mobile phone especially, when is working, the transmitting antenna is placed very close to the user head, arise the question whether people who use it could be exposed to hazardous levels of electromagnetic radiation. Nowadays, due to the advanced development of wireless communication technologies, an increase number of occupations has shifted towards the usage of wireless devices, including cameraman when using Wireless Video-camera. Thus, cameramen are exposed to the EMF emitted by the Wireless Video-camera where this has increased the risk of health effects towards them. The thesis focuses on the investigation of effect of Wireless Video-camera to cameraman wearing RF shielded hat that can protect them from EMF exposure. The aim of this thesis is to add a new layer of shield on top of the hat that can protect cameraman from EMF exposure. This project focus on ordinary, adjustable size and comfortable hat. The hat is sewn with microwave absorber sheet, acted as a shield from RF-EMF. The effects of RF-EMF exposure on cameraman were investigated for cognitive performance, well-being, EMF perception and physiological parameters. The study aims to test whether exposure from Wireless Video-camera may affect cognitive performance, well-being, EMF perception and physiological parameters on cameraman and whether RF Shielded Hat that worn by cameraman can reduce the effect of exposure to RF-EMF fields. Two types of exposure conditions were considered: sham (no exposure) and wireless video-camera exposures and twenty healthy subjects were involved in this experiment. The two-way Analysis of Variance (ANOVA) revealed that there was no statistically significant ($P$>0.05) difference between with and without wearing RF Shielded Hat, and between the two signals (Sham and Wireless Video-camera exposures) except for PAL total error (adjusted) and RVP test. During the Wireless Video-camera exposure with RF Shielded Hat in well-being subjective symptoms, there was no significant difference ($P$>0.05) between the Sham and active exposure in any subjective symptoms, indicating that none of the symptoms that were experienced were related to the Wireless Video-camera exposure. The investigations are extended further to investigate the EMF perception from the subject. Majority of subjects perceived that they can feel the RF-EMF radiation in both exposures (Sham and Wireless Video-camera signals). The results showed that for physiological parameters with RF Shielded Hat between Sham and Wireless Video-camera signal exposures there was no statistically significant ($P$>0.05) for all the physiological parameters except for systolic blood pressure ($P$<0.05). This research has led to a better understanding exposure effects on the neurophysiological and behavioural of subjects, particularly in the risk of occupational exposure field.

# CHAPTER 1

# INTRODUCTION

## 1.1 Background

The revolution of wireless communication devices in the past decade has increased the number of people exposed to electromagnetic field (EMF). The electromagnetic field (EMF) is ubiquitous everywhere in this environment but it is invisible to the human eye ("WHO: Electromagnetic Field (EMF)," 2016). The increasing of mobile phones usage whether for private or business communication has caused an increase concern on potential negative consequence to our body deriving from exposure to the electromagnetic field radiated by such devices (Bernardi et al., 1996, 2000, 2009; Trunk et al., 2013). When the mobile phone is used, the transmitting antenna is placed very close to the user head, arising the question whether people who use it could be exposed to hazardous levels of electromagnetic radiation.

In the past, exposure to EMF is limited to specific occupations, but nowadays due to rapid development of wireless communication, the number of occupations exposed to EMF were dramatically escalating. In particular, one of the jobs in which wireless communication has been deployed is cameraman. The requirement of wireless devices for external shots and studio programmes that demand quick changes, leads to the introduction of wireless video-cameras. The transition from analogue to digital transmission also has made the use of wireless video-cameras become more important (Bernardi et al., 2009).

However, protecting the health of workers who were exposed to the RF-EMF has been one of the problems that needs to be handled wisely (Bernardi et al., 2009; Repacholi et al., 1998). Therefore, the international association such as IEEE Standards Association (IEEE-SA) and independent scientific organizations have both developed international guidelines and issued limits for a safe exposure with the scientific rationale for these guidelines (ICNIRP, 1998; IEEE, 2006). Therefore, the study of occupational exposure of a Wireless Video-camera has become a timely task. Such study will be addressed in the thesis, by considering a standard wireless video-camera in typical operating conditions (Bernardi et al., 2009).

A significant amount of research has been conducted and reported in the open literature related to RF EMF exposure (Cinel et al., 2008; Cursio et al., 2004, 2008; Eltiti et al., 2007, 2009; Koivisto, 2000a, 2000b; Kwon et al., 2012; Luria et al., 2009; Oftedal et al., 2007; Rahim et al., 2014, 2015; Regel et al., 2006). To investigated this problem, experiment on behavioral (cognitive performance, well-being subjective symptoms and EMF perception) and physiological parameters was carried out.



## 1.2 Problem Statement

The emergence of many other technologies that is related to RF-EMF exposures emitted by wireless device, including mobile phone, base station and Wireless Fidelity (Wi-Fi) access points raises a concern about the possible health effects due to the radiation coming from those devices.

Several studies have shown an association between exposure to the RF-EMF from mobile phone and human neurophysiology and cognitive function whereas there is weak evidence that Universal Mobile Telecommunications System (UMTS) 2100 MHz exposure affects human's well-being. Despite the fact that several researchers have presented

evidence of that GSM mobile phone radiation affects human physiology, the effects of the Wireless Video-camera on the human body has yet to be explored.

Since the close contact of the radiating elements with the head when people are using mobile phone resembles when the cameraman are operating Wireless Video-camera leaned on the shoulder or in "steadicam' mode, exhibiting a closer distance between the antenna of the camera and the body, this raises the concern whether a close proximity of Wireless Video-camera to the human body may attribute to the possible adverse health effects of the cameramen. "Steadicam" mode refers to a position of Wireless Video-camera was held up in front of the body or in particular, it can be directly kept by the operator through a handle located on the upper face of the camera itself or it can be held by a mechanic arm attached to a special jacket worn by the cameraman (Bernardi et al., 2009). In addition, based on the survey conducted on a random group of cameraman prior to the experimental investigation in this work, some of them claimed that they experienced some impairments on their well-beings such as dizziness, headaches and fatigue that occured when they used a Wireless Video-camera, caused by low levels of exposure to EMF in the workplace. Thus, pertaining to these complaints, this is another main purpose of this project consideration.



## 1.3 Objective of Study

There are several objectives that have been identified, which give the overall view of this project. These objectives cover all processed from the beginning of the project until its completion. The main objectives are as follow:

1. To propose RF Shielded Hat for protecting cameraman head by adding a new layer of shield.

2. To investigate the Wireless Video-camera field exposure and Sham including with and without RF Shielded Hat on cognitive performance, well-being, EMF perception and physiological parameters (body temperature, blood pressure and heart rate) on single blind, counterbalance and crossover condition.

The main contribution of this project

i) Design the RF Shielded Hat

ii) Investigation on cognitive performance, well-being, EMF perception and physiological parameters

## 1.4 Scope of Study

In this projects, a new layer of shield was added on RF Shielded Hat made from Microwave Absorbing Sheet. The project was undertaken because there were complaints from the cameramen about symptoms of dizziness, headaches and fatigue that occured when they were exposed to the Wireless Video-camera during their work. This project focuses on the ordinary, adjustable of size and comfortable hat. The main scope of this research is to investigate the Wireless Video-camera effect to cameraman head and the RF Shielded Hat acted as protective hat that shield cameraman's head from Wireless Video-camera exposure (Bernardi et al, 2009). This study presents the experimental investigation on the cognitive performance, well-being, EMF perception and physiological parameters, i.e., body temperature, blood pressure and heart rate of cameraman. This will test the hypothesis whether a relationship exists between Wireless Video-camera and cognitive performance, well-being, EMF perception and physiological changes. The changes

in cognitive functions, well-being, EMF perception and physiological parameters of subjects during the active exposure (including Sham) were determined by applying statistical techniques.

## 1.5 Outline of the Thesis Structure

Following the introductory chapter, the rest of the thesis is organized as follows:

Chapter 2 presents the literature reviews on wireless video-camera, background of RF EMF exposure, cognitive test, EMF perception, well-being, physiological parameters and other related work.

Chapter 3 describes the methodology of the studies, flow chart and measurement setup for wireless video camera in details. The CANTAB software is used to analyze the data obtained from the cognitive test.

Chapter 4 summaries all the related results in investigations of the effects of Wireless Video-camera exposure using RF Shielded Hat acted as protective hat that shields cameraman's head from such exposure. The analysis was performed by applying statistical technique to quantify the effect of Wireless Video-camera on cognitive function performance, well-being conditions, EMF perception and physiological parameters (body temperature, blood pressure and heart rate).

Chapter 5 presents the research conclusion and some recommendations for the future work related to this research.

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 Introduction

This chapter covers an introduction to radio frequency and EMF (Electromagnetic Fields) and description of electromagnetic interactions with neurobehavioral. The basic concepts of human exposure to RF-EMF field are described briefly along with the parameters that were studied, including cognitive performances, well-being subjective symptoms, EMF perception and physiological parameters.



## 2.2 Electromagnetic Field (EMF)

The exposure of humans to electromagnetic fields is expressed by using the abbreviation EMF. EMF exposure covers a frequency range between 0 Hz to 300 GHz. (Bhatt et al., 2016; "Wireless Power Consortium: Electromagnetic Field Limit," 2016). EMF also is known as electromagnetic radiation (EMR) and electromagnetic energy (EME). Electromagnetic fields can be found around us such as the sun, earth, and also in electrical appliances such as computers, refrigerators and microwave oven. (European Commission, 2015; Faruque, 2015; "NASA: The Electromagnetic Spectrum," 2016; "Wireless Power Consortium: Electromagnetic Field Limit," 2016). EMF is a physical field produced by electrically charged objects. It affects the behaviour of charged objects in the vicinity of the field. The field can be viewed as the combination of an electric field and magnetic field. The electric field is produced by stationary charges and the magnetic

field by moving charges (current) ("World Health Organization (WHO): Electromagnetic Field (EMF)", 2016).

Electric and magnetic fields are part of the electromagnetic spectrum energy which extends from static electric and magnetic fields (Wireless Power Consortium: Electromagnetic Field Limit, 2016). Non-ionizing radiation is energy which the waves is too small to ionize the tissues (Wireless Power Consortium: Electromagnetic Field Limit, 2016). RF-EMF radiation falls within the non-ionizing part of electromagnetic spectrum with a frequency range of 3 kHz to 300 GHz (Bhatt et al., 2016). Figure 2.1 shows the electromagnetic spectrum in the nonionizing section.

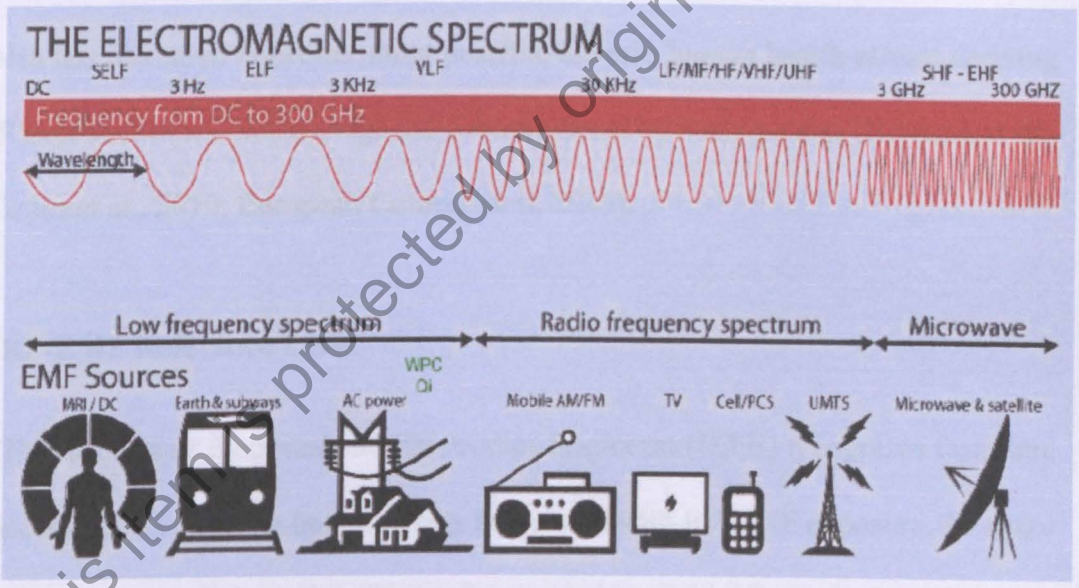


Figure 2.1: An electromagnetic spectrum in the nonionizing section (Wireless Power Consortium: Electromagnetic Field Limit, 2016).



### 2.2.1 Overview of Radio Frequency Electromagnetic Field Exposure to Human

Wireless internet technology or better known as Wi-Fi was introduced in the mid-1980s but it was only began to be widely used in the mid-2000s. Nowadays, wireless internet is prevalent in schools, university, homes, and other public places (Copes et al., 2010). Wi-Fi is known as a new communication technology that utilizes the RF band for

communication purposes. This exposure also has been exposed to the public for decades. Other than Wi-Fi, many other technologies also use the RF band, including mobile phones, base tower infrastructure, radio, television, and microwave ovens as people depend heavily on this electromagnetic wave in present day. Despite all these technologies, most of the research in RF related to possible health effect focused mainly on the mobile phone. It is important to know that Wi-Fi only represents a small part of individual's overall RF exposure in terms of distance (from source), duration, frequency of exposure and power density. Many of the previous literature focuses on potential health effects of RF caused by mobile phones (Bernardi et al., 2009; Copes et al., 2010; European Commission, 2015). The recent increased fenomena of Wi-Fi devices and widely used mobile phone also has increased concerns about possible adverse human health effects deriving from RF exposure to the electromagnetic fields radiated by such devices (Bernardi et al., 2009; Copes et al., 2010; European Commission, 2015).



### 2.2.2 RF-EMF Reference Level

The institute of Electrical and Electronics Engineers (IEEE) recognizes that there were concerns about possible health effects associated with RF EMF exposure. To make public more understand about the effects of currents induced in the body from exposure to RF EMF or from grasping conducting objects that are exposed to RF field, they made numerous efforts to establish safety standards, recommendation and guidelines for exposures to RF and microwave energy (IEEE, 1999). IEEE gives recommendations to prevent harmful effects in human beings exposed to electromagnetic fields in the frequency range from 3 kHz to 300 GHz (IEEE, 1999). The recommendations are intended to apply to exposures in controlled, as well as uncontrolled environments. There are many of panel including scientists and medical experts are involved in issuing these guidelines that have

the aim of protecting people from levels of exposure to RF EMF fields that are known to be harmful (IEEE, 1999, 2006; Lim. J., 2006; Perentos, 2013).

Apart of agencies such as IEEE, there are other agencies that are involved in establish guidelines for exposures to RF and microwave energy. The International Commission on Non-Ionizing Radiation Protection (ICNIRP) has regulatory guidelines that limit the exposure to EMF to avoid known adverse health effects (Herbertz, 1998; ICNIRP, 1998; Lim, 2006; Perentos, 2013). The guidelines includes the publications from 1998 (0 Hz to 300 GHz) and 2010 (0 Hz to 100 kHz). This guideline were examined by the ICNIRP committee and have been reviewed by more than 35 national expert committees and also based on related scientific publications. The contents of the guidelines is for occupational exposure and general public exposure basic restrictions, see tables below. The exposure to general public are specifically for consumer applications. The aim of the restriction was to prohibit whole-body heat stress and extreme localized heating of human tissue by exposure to RF radiation. To ensure that the basic restrictions is not exceeded, reference levels are issued for practical exposure assessment purpose, see Table 2.1.