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# A SAFETY DRIVEN REVIEW OF WEARABLE AND A PROPOSED SAFETY FRAMEWORK

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**Abstract**

As computers move from the desktop, to the palm top, and onto our bodies and into our everyday lives, infinite opportunities arise to realize various applications that have never before been possible. As wearable technologies such as the Google Glass, Earbuds are developed and released to the public, health problems resulting from volume of rays that are penetrating human bodies through the signal emissions from these devices must be acknowledged and accounted for. This paper presents wearable computer devices their uses, hazards and the need for the adoption of global safety standards in order to make them safe for users. It also proposed a framework for evaluating the safety use of the wearable devices.

***Keywords***: *wearable, emissions, hazards, standards, EMI, SAR*

## Introduction

With the growing acceptance of multimedia and the Internet, desktop computers are becoming all-purpose information appliances, incorporating everyday devices such as the telephone, fax, answering machine and television. However, these computers are still connected to the desk and are not available to the user during most of the day. By designing a networked, multimedia computer that can be worn as clothing or is built into the user's clothes, the power of computing can assist everyday tasks. Wearable computers allow a much closer association with the user. In replacing the consumer electronics listed above, sensors are added which allow the Wearable to see what the user sees, what the user hears, sense the user's physical state, and analyze what the user is typing (Starner, et al., 1997).

## Wearable Devices

A wearable computer device is a computer worn on any part of the body and is highly personal (Chittaro, 2003). While the technology is still novel, a few researchers and hobbyists have adopted wearable computers into their everyday lives. These users are often seen wearing their head-up displays or typing on one handed keyboards in a wide variety of situations.

A wearable computer is a computer that is subsumed into the personal space of the user, controlled by the user, and has both operational and interactional constancy i.e. it is always on and always accessible (Starner, et al., 1997). Most notably, it is a device that is always with the user in an unobtrusive manner, and into which the user can always enter and execute commands.

Wearable computing devices have the following attributes:

a) Constancy: The signal flow from human to computer and computer to human as depicted in Figure 1. It runs continuously to provide a constant user interface.

b) Augmentation: Traditional computing paradigms are based on the notion that computing is the primary task. Wearable computing, however, is based on the notion that computing is *not* the primary task. The assumption of wearable computing is that the user will be doing something else at the same time as doing the computing thus, the computer should serve to augment the intellect, or complement the senses.

c) Mediation: Unlike hand held devices, laptop computers, and PDAs, the wearable computer can encapsulate us. It does not necessarily need to completely enclose us but the concept allows for a greater degree of encapsulation.

Other important attributes of wearable computers include the non-monopolizing of the user's attention, unrestrictive to the user, observable by the user, controllable by the user, attentive to the environment, communicative to others (Bodelid & Oscarsen, 2002).

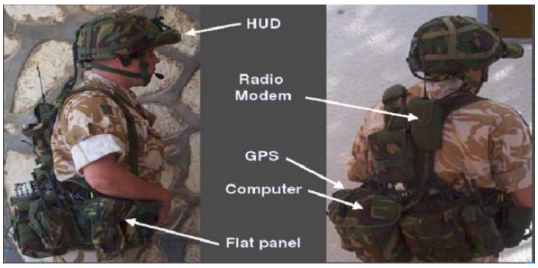

*Figure 1: Integration of wearable computing devices into a soldier's webbing*

### Other examples of wearable computing devices

**a) Earbuds**

*Figure 2: Earbud (Sean, 2016)*

The Earbuds or earphones in the context of telecommunication, is a combination of headphone and microphone. Headphones either have wires for connection to a signal source such as an audio amplifier, radio, CD player, portable media player, mobile phone, electronic musical instrument, or have a wireless device, which is used to pick up signal without using a cable.

The different types of headphones have different sound reproduction characteristics. Closed-back headphones, for example, are good at reproducing bass frequencies.

Headphones that use cables typically have either a 1/4 inch jack or a 1/8 inch jack for plugging the headphones into the sound source.

Earbuds are very small headphones that are fitted directly in the outer ear, facing but not inserted in the ear canal. Earbuds are portable and convenient, but many people consider them to be uncomfortable and prone to falling out. They provide hardly any acoustic isolation and leave room for ambient noise to seep in; users may turn up the volume dangerously high to compensate, at the risk of causing hearing loss. On the other hand, they let the user be better aware of their surroundings. Since the early days of the transistor radio, earbuds have commonly been bundled with personal music devices. They are sold at times with foam pads for comfort. It can measure the wearer's heartbeat through their ears (Randewich, 2014).

An example of Earbud that measure real time heart rate is LG HRM Earphone (FR74), fully compatible with life band touch activity tracker for signal transmission this is shown in figure 3.

*Figure 3: Heart Rate Monitor Earphone (Sean, 2016)*

**b) Fitbit Ultra**

Fitbit Ultra activity tracker. This is device uses a three-dimensional accelerometer, similar to that in the Wii Remote, to sense user movement. The Tracker measures steps taken, and combines it with user data to calculate distance walked, calories burned, floors climbed, and activity duration and intensity. It uses an organic light-emitting diode (OLED) display to display this and other information such as the battery level. It also measures sleep quality by tracking periods of restlessness, how long it takes the wearer to fall asleep, and how long they are actually asleep (New Health Advisor, 2015).

A wireless base station is included to receive data from the Tracker and also charge its battery. When connected to a computer the base station will upload data to the Fitbit website, where a number of features are available: seeing an overview of physical activity, setting and tracking goals, keeping food and activity logs, and interacting with friends.

The Fitbit Classic tracked only steps taken, distance travelled, calories burned, activity intensity, and sleep. It was designed to be a small black and teal device that could be clipped discreetly onto clothing and worn 24/7. This is displayed in figure 4.

*Figure 4: Fitbit Ultra activity tracker (Fitbit Device, 2014)*

**c) Google Glass**

The Google Glass is a small headband-like computer that puts a screen in front of the user's eye, allowing them to navigate the web, take pictures, and manage their various social media and communication. The device contains a wide-angle camera, retina sensor, microphone, and touch screen for device navigation. Users can easily shoot video clips or take pictures at the utterance of a command, and already there exists the ability to create custom applications for the device using Google's "Mirror-API", a web-based API that allows developers to interface with a Glass unit. The Google Glass is the latest and most cutting edge product developed by Google, and is the object of many a technology aficionado's desire. Because Google Glass is targeted to be as affordable as a smartphone and has caught the eye of so many tech-savvies, it is almost certain that these objects will become commonplace in our ever changing, ever upgrading society. As a result, it is of utmost importance that people should be aware of the consequences of the use of such unprecedented hardware in order to protect our own personal information, privacy, and safety. The Google Glass is among the first high-tech products developed that are intended to be worn on the user's person as an accessory. The concept of wearable technology has been developing for some time now, and although advanced wrist watches have been around for a while, nothing truly compares to a pair of pseudo-glasses interfacing with your surroundings and physical/auditory input. However, regardless of how the device actually works, wearable technology poses a serious risk to both the user of the device and those around them (Stone, 2013).

**d) Heads-Up Display (HUD)**

The Head-Up Display (HUD) creates a new form of presenting information by enabling a user to simultaneously view a real scene and superimposed information without large movements of the head or eye scans (Asai, 2010). HUDs have been used for various applications such as flight manipulation, vehicle driving, machine maintenance, and sports, so that the users improve situational comprehension with the real-time information. Recent downsizing of the display devices will expand the HUD utilization into more new areas.

The HUD basically has an optical mechanism that superimposes synthetic information on a user's field of view. Although the HUD is designed to allow a user to concurrently view a real scene and superimposed information, its type depends on the application. HUDs are categorized into three design types: head-mounted or ground-referenced, optical see-through or video see-through, and single-sided or two-sided types.

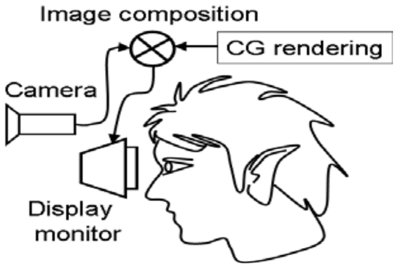

*Figure 5: Optical see-through HUD (Asai, 2010)*

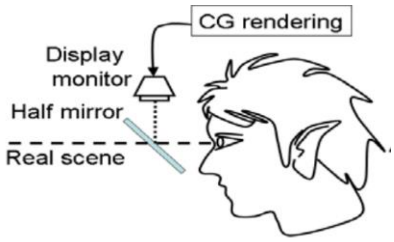

*Figure 6 - Video see-through HUD (Asai, 2010)*

The benefits of HUDs are mainly characterized by visual scanning and re-accommodation. In the visual scanning, HUDs reduces the amount of eye scans and head movements required to monitor information and view the outside world. The traditional HUD causes time sharing between the tasks. For example, drivers must take their eyes off the road ahead in order to read the status at the control panel, which affects driving safety (Asai, 2010).

### Emissions in Wearable Devices

The rapid development of wearable devices has indicated that it will become part of the human future in making life easier for mankind. However, it is an established fact that these devices emit radiations as do all other communication devices. These wearable devices are completely strapped to the body of the user possibly all day and hence, the radiation emitted is directly been absorbed into the user's body. Today, there is yet to be an acceptable standard on the measurement of the radiation emitted by these wearable devices.

In the section following, a review of global Electromagnetic Interference (EMI) radiation standards are examined and a cross comparison is made while proposing the path way to the safe use of wearable devices.

### EMI Emission Standards

Communication devices emit energy in the form of RF signals referred commonly as EMI. The energy (EMI) radiates in the environment and they are absorbed by the human bodies around the environment. This energy at high level of absorption could become injurious hence the absorption rate into the Human body is referred to as the Specific Absorption Rate (SAR), (ICNIRP, 1998). Emission standards have been set up by government institutions in various countries in order to protect the people from being affected by the hazardous emission of these Radio Frequency (RF) signals.

In 2013, the IEEE compiled the permissible exposure limits as specified by the U.S. government and the results are presented below.

**Table 1: Specific Absorption Rate (SAR) and Maximum Permissible (MPE) standards and limits in a controlled environment (IEEE, 2005)**

| Frequency Range (MHz) | E-Field Strength (E) (V/m) | Magnetic Field Strength (H) (A/m) | Power Density (S) (mW/cm$^2$) | Averaging Time $\|E\|^2$, $\|H\|^2$ or S (minutes) |
|---|---|---|---|---|
| 0.3 – 3.0 | 614 | 1.63 | (100)* | 6 |
| 3.0 – 30 | 1842/f | 4.89/f | (900/f$^2$)* | 6 |
| 30 – 300 | 61.4 | 0.163 | 1 | 6 |
| 300 – 1500 | - | - | f/300 | 6 |
| 1500 – 100,000 | - | - | 5 | 6 |

*f = frequency in MHz* **Plane-wave equivalent power density*

In a controlled environment the US and Canada approved the SAR of 8.0 Watts/kg (W/Kg) averaged over 1 gram of tissue while the EU and rest of world recommended 10.0 Watts/kg averaged over 10 grams of tissue. For hands, Wrist, Feet and Ankles (Extremities) the US and Canada approved 20.0 Watts/kg averaged over 10 gram of tissue while EU and rest of world recommended 20.0 Watts/kg averaged over 10 grams of tissue.

**Table 2: Specific Absorption Rate (SAR) and Maximum Permissible (MPE) standards and limits in an uncontrolled environment (IEEE, 2005)**

| Frequency Range (MHz) | E-Field Strength (E) (V/m) | Magnetic Field Strength (H) (A/m) | Power Density (S) (mW/cm$^2$) | Averaging Time $\|E\|^2$, $\|H\|^2$ or S (minutes) |
|---|---|---|---|---|
| 0.3 – 1.34 | 614 | 1.63 | (100)* | 30 |
| 1.34 – 30 | 842/f | 2.19/f | (180/f$^2$)* | 30 |
| 30 – 300 | 27.5 | 0.073 | 0.2 | 30 |
| 300 – 1500 | - | - | f/1500 | 30 |
| 1500 – 100,000 | - | - | 1 | 30 |

*f = frequency in MHz* **Plane-wave equivalent power density*

In an uncontrolled environment the US and Canada approved 1.6 W/kg averaged over 1 gram of tissue while the EU and rest of world approved 2.0 W/kg averaged over 10 grams of tissue. For hands, Wrist, Feet and Ankles (Extremities) the US and Canada recommended 4.0 W/kg averaged over 10 gram of tissue while the EU and rest of world maintained 4.0 W/kg averaged over 10 grams of tissue.

The SAR for various devices have been developed and presented in the safety codes for the usage of RF emitting devices for various countries. In the US for example, standards for various RF emitting devices such as fixed installation RF devices, portable devices, mobile devices have been defined however, a closer look at wearable devices in the code provided has no specific SAR definition for wearable devices (Moulton, 2010). Interestingly, the use of devices which emit RF signals which today are commonly referred to as wearable body devices is increasing. These devices in themselves are providing improved services to mankind but the question is; what is the health implication of the use of these devices over a given period of time?

The major concerns are that these wearable devices which communicate and transmit data and emit RF signals into body tissues that they are strapped to have the potency to create electromagnetic fields which may be harmful to the health of the users as already expressed in many forums and letters of complaints lodged with the Federal Communications Commission (FCC) of the United States.

### Review on the effect of the emissions on humans

Electromagnetic radiation is emitted by many natural and man-made sources and is a fundamental aspect of our lives. We find these RF emitting devices as valuable tools in our day-to-day lives and indeed they are. The sun emits rays that helps to keep us warm, the radio frequencies which we use in our daily communication across long distances and now the new wearable devices such as the Google Glass, Earbuds that monitor heart rate, *Fitbit ultra*-activity tracker, *Hexoskin*, a sports wear which monitors ones cardiac activity and *Recon Jet heads-up* which is a heads-up display for sports that delivers relevant information at a quick glance. Indeed these devices have been introduced to make living better.

Based on a large amount of historical knowledge, national and international exposure limits have been established to protect the general public against adverse effects associated with acute RF energy exposures but, what definable standards have been established for wearable devices?

Articles have been published and experiments conducted that prove that sufficiently intense RF energy can cause heating of materials with finite conductivity, including biological tissues. A number of well-established biological effects and adverse health effects from acute exposure to intense RF energy have been documented (WHO, 2007). For the most part, these effects relate to localized heating or stimulation of excitable tissue from intense RF energy exposure.

Some users of these wearable devices have complained of headaches like in Google Glass. These devices become warm or heated up while online. This shows that RF signals are been deposited or absorbed by the human tissues to which they are strapped.

Recommendations on use of RF devices have always been predicated on a given distance range however, with wearable devices the distance is zero as they are strapped to the human body and thus, absorption of the RF signals into the human tissue is even more accentuated. Levels of absorption over time which could become injurious to the human is what should be determined and established in order to have safe wearable devices for use of mankind.

### Proposed Framework

1. **Input**: Signal radiation values will be collected from different wearable devices.
2. **Simulation**: The values will be fed into a simulator to determine predicted quantities of radiation being gathered into the human body over time.
3. **Projection**: Considering the fact that some people use several wearables at a time and over extended periods of time, a projection will be made to predict what quantity of radiation is accumulated in the body with what devices over a particular period of time.
4. **Analysis**: Specialists in that area will be able to determine the impact of different quantities of radiation on different parts of the human body over the projected time.
5. **Report**: At this point, it will be necessary to circulate a report to the manufacturers, government, health bodies, the people and all other stakeholders to create awareness for those who are going to use it. At this point, if it is discovered that the quantities or radiation accumulated over a period of time are excessive and unsafe, the government and other controlling bodies could stop the manufacturers from releasing the product. Also, the report should be able to inform users what devices not to use together, the recommended amount of time to use them in a stretch so that the accumulated levels of radiation are not unduly increased.

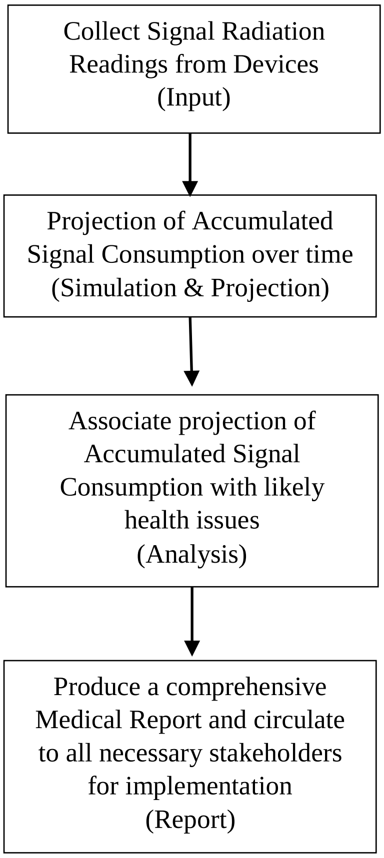

*Figure 7: Proposed framework for safety limits and regulations*

## Recommendations

### Need for Safety definition (of wearable devices)

As important as computer devices are to mankind, they cannot be placed at a higher priority above the life of human beings that exploit their advantage for work satisfaction. Therefore, there should be an approved frame work to which all developers of these wearable devices must conform to. As it is now, the industry is so uncontrolled that every manufacturer makes at will and releases to the market for public consumption without any internationally set standards.

### Need for international standards on EMI emission of wearable devices

It is recommended that the health sector should establish a standard measure of maximum signal emissions the wearable devices can emit that will not have a short/long term effect on human lives and this should be implemented via the effective laboratory measurement of the manufactured wearable devices in meeting globally set and approved standards.

### Setting safety limits and regulations

There are different wearable devices placed on human body parts or sense organs, thus, there should be a threshold limit of emission each organ can tolerate. Safety EMI limits should be set for devices that will be placed on sensitive body parts such as the eye etc.

Furthermore regulations should be set to control the competitive technological production of these devices in order to test them for emission limits before they are released to the public while placing penalties for defaulters.

## Conclusion

Use of wearable devices is on the increase as the technology keeps evolving in such a way that it appeals to the minds of the general populace, both young and old. However, it is also clear from research that prolonged use of these devices could lead to accumulation of certain quantities of radiation over time, which could negatively affect human health. A framework has been proposed which will enable all involved stakeholders to control the use of these devices and minimize the risk of high quantities of radiation being accumulated in the human body.

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