Wireless Transmission and Its Relation to the Human Body

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Introduction

Wireless technologies are all around us in this current age. Whether for health, work, or entertainment, wireless technologies remain vital to our lifestyles. The wireless medical device field is one such example that is seeing rapid gains in development. Sensors ranging from heart rate sensors, EEG sensors, glucose sensors, and pH sensors are being developed every day. These devices have risks and limitations because they are worn close to the human body. It is imperative to consider the risks and limitations of the underlying physics when designing future wireless devices.

Importance of Wireless Transmission

General Case

The main benefit for developing wireless devices is to "eliminate the clumsy and restrictive wirings and increase patient autonomy and mobility [1]." The device can be accessed and controlled by a single distant device such as a phone. These benefits are so important that the wireless health industry is growing by leaps and bounds.

Some examples of these medical devices currently include wireless blood pressure monitoring systems, wireless oximeters, and even wireless EEGs. These systems are also being equipped with temperature sensors, sweat sensors, 3-D accelerometers, and gyroscopes [1]. Although these sensors provide important data, without easily accessible data, the results are wasted.

Wi-Fi

Wi-Fi is a common wireless technology utilized in wireless local area networking (WLAN), using the IEEE 802.11a/b/g standard. Wi-Fi primarily operates in the 2.4GHz Industrial, Scientific, Medical (ISM) frequency band, but recently has added the 5GHz band due to the congestion of the 2.4GHz band. Wi-Fi has high data transport capacity, fast communication speed, and a long range of less than 100 meters, making it is widely used in providing wireless internet access to homes, businesses, and public areas. Wi-Fi's main drawback is its high power consumption, making it unsuited for wearable devices. It also transmits radio frequency [2].

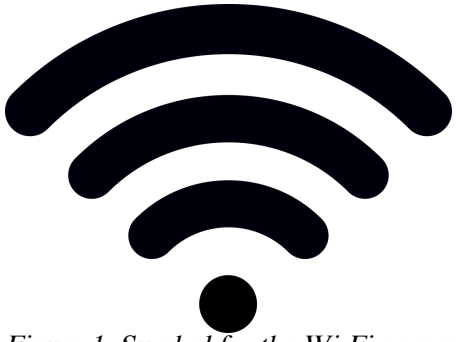

Figure 1. Symbol for the Wi-Fi communication standard

Bluetooth

Bluetooth is a global wireless technology standard designed for short range, low power, and low cost using the IEEE 802.15.1 standard. Bluetooth operates on the 2.4 GHz unlicensed ISM (Industrial, Scientific, Medical) band. Bluetooth uses channels of 1MHz bandwidth with 79 channels in most countries, but only 23 channels in some. It operates on frequency hopping, changing its channel and thus frequency many times a second. The FCC limits Bluetooth to only one watt peak power output and requires 75 out of 79 channels to be used in frequency hopping. This reduces the interference Bluetooth makes in the ISM band. With its low power and short range of about 10 meters, it is well suited for wearable devices and has seen much use in the medical field [3].

Figure 2. Symbol for the Bluetooth communication standard

Senior Design Project

Understanding the science behind wireless transmission will be useful for developing the oral biosensor for this senior capstone project. In this project, the modular circuit for the oral biosensor will consist of a pH sensor and computer chip housed within the mouth. The effective use of wireless transmission will make the sensor data easily accessible on a smartphone device.

Bluetooth is the desired communication standard for this biosensor circuit because of its short range and low power consumption. Wi-Fi in contrast wastes too much energy on spreading its transmission over a large area.

Limitations of Wireless Transmission

Transmission Through the Human Body

For all the benefits wireless transmissions provide, various limitations of the technology impact their performance. The primary limitation is the large transmission losses occurring when travelling through the human body. This occurs because of the conductivity, dielectric constant, and thickness of various tissues and organs in the body [4]. Another important factor to account for is the frequency of transmission. Lower frequencies can bypass the body with less loss, but result in lower bandwidth. High frequencies face more attenuation, but can carry more information. Finding a balance between these factors to minimize the transmission loss is imperative for a properly functioning wireless device.

Implantation on the Human Body

Wireless transmissions are also limited by the body's effect on antennas. An antenna's "radiation and impedance matching" will be significantly degraded when embedded in the human tissue or placed directly on or near the surface of a human body [4]." Specifically, in one study, the performance of the RF circuit takes a hit when within 0.5mm of the human body [5]. Overall, these effects are important for designing wireless devices both implanted on the body and in the body.

Risks of Wireless Transmission

One of the most important things to keep in mind about wireless transmissions is its safety. Wireless transmissions are primarily made up of electromagnetic waves known as radio frequency (RF). RF radiation has been studied extensively over the decades and numerous results show that large amounts of RF, from MRIs and X-rays for example, can cause biological and health effects. Because of this, the guidelines are set such that the specific absorption rate (SAR) stays below 0.08 W/kg. Bluetooth and Wi-Fi operate below the ionizing level, so RF waves generated do not break the chemical bonds in the human body.

Scientists are however uncertain of the effects of long-term exposure to low-level radiation. While some organizations concluded that "exposure to RF electromagnetic fields, including those used by mobile phones, is 'possibly carcinogenic' to humans," other organizations say that those risks are explained by errors or biases. Currently, the FCC states no scientific evidence suggests a link to cancer,
but with the uncertainty of the RF effects, it may be important to limit excess RF from affecting the

human body [6].

Conclusion

Designing Around These Problems

Most of these limitations and risks are non-negotiable when it comes to wireless medical devices. Often, the wireless device must be embedded in or on the human body and therefore suffer from antenna or transmission losses. Often, the wireless device will be constantly communicating, using RF, with an external device. While engineers cannot mitigate these risks and limitations completely, they can study the human body to determine the most effective transmission path, or we can optimize the RF transmission to only reach a short range. Overall, the future of wireless technologies is bright, but it remains important to optimize around every risk and limitation.

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