Human Body Communication Using Galvanic Coupling

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Introduction

Galvanic coupling is a method for injecting an electrical communication signal into the body. The body acts as the communication channel and the injected signal is transmitted primarily through the skin. Normally, devices on the body communicate wirelessly through radio frequency (RF) technology. However, galvanic coupling provides a more power efficient and more secure means of communication. These advantages make galvanic coupling useful for many applications, especially in the medical field. This report discusses these applications, how galvanic coupling works, its advantages over other communication techniques, and electrical properties of the body that affect galvanic coupling.

Applications

In the world of healthcare, there is currently a large demand for remote and continuous patient monitoring [1]. Many doctors wish to monitor vitals such as heart-rate and blood pressure. There is also a pressing need for smart medical devices to help treat patients remotely, such as an automated drug delivery system and neural stimulation for epilepsy and chronic pain prevention [1]. In order for these devices to communicate with a doctor, they need to be connected to a network. Some of the current networks use wired connections, which are inconvenient to the user externally and can cause internal infections [1]. Other networks aim to solve this problem by communicating wirelessly using radio-frequency technology, but this requires power levels that many devices, especially medical implants, are not able to provide. This power problem can be solved with intra-body communication using galvanic coupling. This is especially convenient for implants because the signal can be transmitted through the tissue efficiently and therefore is more power efficient than RF communication which is absorbed by tissue [1]. A network could be constructed using galvanic coupling and have all of the devices communicate to a common node such as a smartwatch. That node could wirelessly transmit the data using Bluetooth or Wi-Fi to a doctor in a separate location [2]. Because of its many advantages in power and security, intra-body communication through galvanic coupling will have many more applications in the future.

How It Works

Galvanic coupling is a method of inserting an electrical signal into the body for intra-body communication.

There are two different kinds of electrical current: direct current (DC) and alternating current (AC). Direct current travels in one direction and does not change. Alternating current can switch directions or vary in magnitude, usually at a specific frequency. In galvanic coupling an alternating current is injected into the skin. The skin acts like a wire and carries the signal throughout the body. This signal causes a voltage to appear across two receiving electrodes elsewhere on the body.

Figure 1. Human Body Communication Using Galvanic Coupling

Because the signal is completely contained within the human body, the performance is not affected by the surrounding environment [3]. However, the body is not a perfect wire and affects the signal in non-ideal ways, one of which is adding a delay [4]. Just like there is a limit on radio frequency transmission power due to safety reasons, there is one for galvanic coupling as well. The maximum allowed contact current is 20 milliamps because 50 milliamps is the current used for nerve stimulation. The injected current must be low enough as to not damage any nerves or tissue, especially when being applied over a long time [5].

Advantages

Over Radio Frequency

The human body absorbs a significant amount of RF waves that are used for wireless communication. RF transmitters also transmit the signal into the environment in all directions [6]. This is very power inefficient and limits the practical use of this communication technique. RF communication can also be affected by interference from the environment. This leads to security issues because an outside source can receive or affect the transmitted signals. Intra-body communication has proven much better than RF communication because the signal is completely contained inside the body. It provides secure, interference-free, energy-efficient communication.

Over Capacitive Coupling

Capacitive coupling is another type of coupling for intra-body communication. Like galvanic coupling, it uses two electrodes. However, in this method, one electrode couples to the body and the other couples to the environment. The signal is extracted by measuring the voltage between the two. Since the signal is coupled to the environment in this method, body movement can distort the signal [3]. Galvanic coupling is better suited for communicating through the body because it is not affected by body movement, giving patients the ability to move.

Effects of the Body

Electrical Properties of Tissue

Although galvanic coupling is not affected by the environment, it is affected by the electrical properties of the human body. The relative permittivity (how well an electromagnetic wave can pass through a material) of skin, fat, muscle, and bone affects the signal [7]. These properties depend on operation frequency, temperature, structure of cellular membranes, tissue water content, and more. As the frequency of the signal increases, different tissues conduct the signal more easily and it penetrates deeper into the body [7]. The most power efficient tissue is skin so this not ideal that the signal spreads to other tissue layers.

Attenuation

Due to the resistive nature of the human body, signal attenuation occurs. That is, the signal strength gets smaller. Signal attenuation increases exponentially with distance when transmitting over the arms and legs [5]. An increase of 5 cm between the transmitter and receiver on the arm can increase attenuation by a factor of 2 to 3 times. Joints can increase the attenuation by a factor of 2.5 times. The larger the joints the more the attenuation [2]. A decrease in muscle resistance leads to an increase in attenuation, and a decrease of fat resistance leads to a lower attenuation because more of the signal remains in the fat layer and does not penetrate to the muscle layer [2]. Although attenuation occurs, it is still possible to recover the signal.

Conclusion

Overall, galvanic coupling is a very effective method for intra-body communication. It is secure because the signal is contained completely in the body. It is more power efficient than wireless RF communication and is more reliable than capacitive coupling. Also, its lack of wires makes its comfortable and hassle free for the patient. Galvanic coupling has many potential applications and could revolutionize the medical field.

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