A Survey of Capacitive Coupling over HBC

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Vital sign monitoring systems such as EEG's tend to be bulky, expensive, and relatively invasive due to the numerous, wired points of contact with the body. Because such monitoring systems are so non-mobile, some patients may have to stay in the hospital days after a major medical event such as a surgery even when it would be perfectly safe for them to spend that time at home. An emerging trend in outpatient monitoring can be seen in the use of mobile medical devices that can be discrete enough to allow for comfortable and unhindered movement throughout the patient's home while still being effective enough that they will detect any major medical event and immediately report the event to the patient's doctor.

A technology that Gold Team considered to make such devices a reality was capacitive coupling over the human body channel (CCHBC). CCHBC allows for multiple devices dispersed across the human body to communicate with each other using only human skin as the communication medium.

Introduction

CCHBC is a method of communication over the human body channel or the medium over which data is sent from device to device. In the case of CCHBC, the useful human body channel is typically confined to the skin. The ability to transmit data across a patient's skin is useful because it allows many distinct sensors to be located on disparate regions of the human body and still be able to communicate without the invasive wires that exist in common hospital monitoring equipment. A sensor network placed around the body could collect data on vital metrics such as heart rate, body temperature, and blood pressure, to name just a few. If these sensor readings were sent wirelessly to the patient's cell phone, then this data could be relayed to the patient's doctor with ease.

Why use HBC?

The communication channel is the physical medium through which data is transmitted. In the case of radio waves, the communication channel is the air, whereas in communication over the human body channel (HBC) data is transmitted over the actual human body.

Though there are multiple methods of communication when using the HBC, they all share the benefits and limitations of the channel itself, namely, human tissue. Typical wireless communication schemes transmit data via radio waves. However, since radio waves can propagate a significant distance in space, these signals can be tapped at a distance introducing the possibility of unauthorized persons intercepting this sensitive medical data. The HBC has inherent properties that make such data interception impossible; to send or receive data on the HBC, the relevant device must be in physical contact with human tissue, negating the potential for interception at a distance [1].

Additionally, since there are no competing signals on the HBC, something that can't be said about radio waves, relatively high data rates can be achieved using parallel transmission schemes.

The unique properties of the HBC allow for the implementation of communication systems that have significant power savings benefits when compared to radio wave communication schemes. Use of the HBC allows for the elimination of power draining, high frequency circuitry by transmitting low frequency, baseband data (something that is not viable with radio waves) [2]. Usage of low frequency transmission signals has the added benefit of increasing transmission efficiency as less of the signal is radiated from the body as radio waves [2].

Tradeoffs Associated with CCHBC

CCHBC is not the only method of communication over HBC. Galvanic coupling, to name another common scheme, has a different set of tradeoffs associated with it when compared to CCHBC.

CCHBC in particular is attractive when compared to alternative communication over HBC approaches because it is not as heavily influenced by human body characteristics that can vary significantly from person to person [3]. Additionally, the transmitting and receiving electrodes in CCHBC systems do not have to be in direct contact with skin which allows for systems integration with clothing [3]. However, these properties come at a heavy price.

A significant drawback to CCHBC is how heavily it is affected by the local electrical environment [3]. Local electrical environments can change significantly over small distances since they are affected by anything from proximity to power lines to amount of metal in the area. CCHBC systems make measurements relative to a reference measurement that is taken from the device's surroundings. If the patient in question is rapidly changing local electrical environments, moving from room to room in a home for instance, the CCHBC system can become highly error prone as it is making measurements that are relative to a baseline that is fluctuating as the surrounding electrical environment changes.

In practice, as long as the local environment baseline fluctuates consistently across all sensor devices, then communication can occur effectively using CCHBC. However, this is often not the case since baseline measurements are affected by physical orientation of the device as much as location. For example, a sensor node located on the torso would have a significantly different baseline reference measurement than a sensor node located on an outstretched arm, as the sensor on the arm is at a ninety-degree angle to the torso sensor. In the previous example, the torso and arm sensor nodes would be incapable of effective communication since they have differing reference measurements.

Communication using CCHBC when baseline measurements vary due to either changing local electrical environments or orientations can cause a measurement value to be scaled significantly and inaccurately when transmitted, which can cause both false positives and false negatives of major medical events.

Conclusion

CCHBC has many attractive qualities; however, the dependence on a static local environment was enough for Gold Team to disregard it as a viable method for communication over the human body channel. The necessity of a static environment entirely disregards the design requirement for our system to be viable as a vitals monitoring system that could be used for patients who want to be able to move unhindered throughout their own home.

However, alternative methods of communication using the HBC (such as Galvanic Coupling) can be explored as they may offer properties that are better suited for the design requirements of Gold Team.

References

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