Demo: Sensor Node Communication Through Conductive Mesh Placed on Cotton Knit Fabric

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Abstract

Our objective is to provide body worn hybrid digital/physical materials to present and feel touch. We propose the use of power-line communications for sensor nodes embedded in a cotton knit fabric with two conductive meshes sewn on both sides of the fabric. We demonstrate that the signal attenuation due to the transmission line capacitance is insignificant. We also observe how a change in the distance between the mesh and fabric affects the signal amplitude, an indicator of the capacitive behavior of the transmission line.

Keywords

Power-line communications (PLC), channel capacitance, embedded sensors in fabrics, conductive mesh

1 Introduction and Motivation

The overall goal of our project is to provide body worn hybrid digital/physical materials to present and feel touch. Such a platform will include a high number of sensors and actuators. The sensor nodes can use a wireless or wired medium for communication. The major design goals are user comfort as well as reliable communication between sensors. Towards this end, wires may make the communication unreliable as the break of wires may disconnect one or more nodes from the rest of the network. In networks consisting of a large numbers of nodes, wiring can increase the fabric weight and consequently cause discomfort. In order to mitigate the issues mentioned, we propose to use power-line communication through the fabrics: we use a single plane for transmitting both data and power to the sensor nodes, i.e., we designate one layer of fabric for power and data transfer and the other layer as ground. We make these conductive layers (i.e., power-data and ground) by sewing a conductive mesh on both sides of a cotton knit fabric. Similar to our work, Wade and Asada [3] proposed a wearable DC power line communication system that uses one wire for power and data transfer and one wire for ground. However, their approach implies that the supply voltage is used for charging/communication. Our approach provides a continuous supply voltage to the sensor nodes and at the same time ensures communications between them, similar to Noda et al. [2]. However, we provide one line (i.e., data and clock) for communication between sensor nodes. This paper demonstrates communication between sensor nodes using a conductive mesh mounted on a cotton knit fabric.

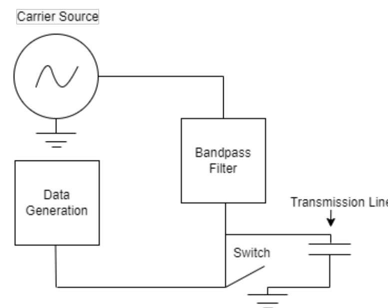

Figure 1. Block diagram of the hardware platform for signal transmission. The higher the capacitance of the transmission line and the frequency of the carrier signal, the higher is the carrier signal attenuation.

2 Hardware Platform

Our platform provides communication between sensor nodes over a power line, with a 5V supply [1]. A carrier signal is generated at a frequency of 1.59 MHz. We use amplitude shift keying (ASK) and Manchester coding for modulation and encoding respectively. Therefore, in comparison to Noda et al. [2], we do not interface with I2C sensors and provide one line for communication (i.e., for both clock and data). The use of Manchester coding leads to a more robust way of extracting the DC component of the signal. We expect the mathematical model of the transmission line (i.e., fabric and mesh) to be a capacitor. Fig. 1 demonstrates how our platform conducts data transmission. Therefore, for a capacitive channel, the higher the carrier frequency, the higher the signal attenuation.

3 Experiment

This demo illustrates that the mesh grid capacitance should possess a low value and therefore we expect the car-

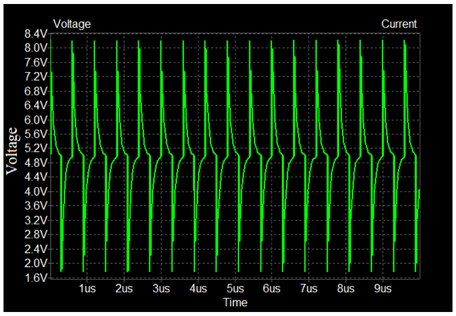

Figure 2. Simulation of the carrier signal when coupled with supply voltage, i.e., 5V. The maximum amplitude of the carrier signal reaches 8.2V. However, in practice, the transmission line capacitance, the capacitance at the input of the voltage regulator and other losses attenuate the carrier signal.

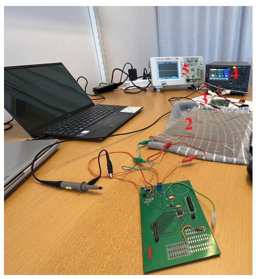

Figure 3. Experiment setup for observing the signal attenuation. 1. Transmitter 2. Transmission channel: two mesh grids sewn on both sides of a cotton knit fabric. 3. Receiver 4. Power Supply (5V) 5. Oscilloscope

rier signal to have considerably low attenuation. We also demonstrate that the carrier amplitude changes as a result of a change in the distance between the mesh and fabric. A pulse carrier signal is generated at a frequency of 1.59 MHz. It has a maximum voltage of 3.3 V. Our simulation results indicate that when a carrier signal with a frequency of 1.59 MHz is coupled with a power line (5V in our case), then the carrier amplitude changes between 2V and 8V as shown in Fig. 2. However, in practice, this range is different due to the line capacitance, the capacitance at the input of the voltage regulator, the load impedance and other losses. Therefore, we prepare the setup shown in Fig. 3. The size of the mesh is 30x21cm. The mesh aperture has a length of 1mm. Fig. 4 shows the modulated carrier signal coupled with 5V and also demonstrates that the signal amplitude varies between 4V and 6V. Also, the figure shows periods where the carrier signal is transmitted and grounded, i.e., it is in accordance with Fig. 1.

We increase the distance between one of the mesh plates and the fabric by almost 3 cm and observe an approximately 40 mV increase in the maximum amplitude of the carrier signal. This is explained by the capacitance behavior of the mesh-fabric structure. Also, the output of the demodulator shows the data transmitted from the sender (Fig. 5). The output of the demodulator indicates a series of pulses with an amplitude of 3V which is the supply voltage of the comparator. Pulses with 1 represent the preamble, high pulses with

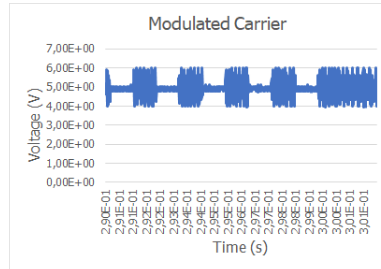

Figure 4. Modulated signal through mesh-fabric structure. The carrier signal varies between 4V and 6V. The DC offset is 5V which is the supply voltage. We use ASK for modulation.

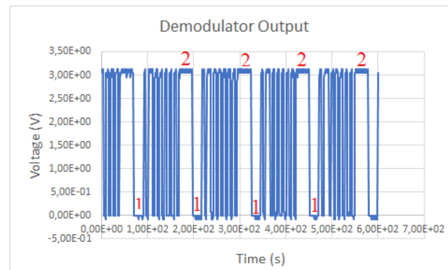

Figure 5. Demodulator output. Pulses with 1 represent the preamble and those with 2 indicate the end of data. The pulses between 1 and 2 are data.

2 indicate the end of data. The pulses between 1 and 2 are the data transmitted. Since we use Manchester coding, an encoded data bit is a transition from low level to high level or vice versa. Therefore, encoding a bit takes twice logic levels and consequently for encoding a byte in our case we observe 16 logic levels (Fig 5). The received data matches the transmitted one.

4 Conclusion

We demonstrated signal transmission over a fabric with conductive mesh attached to it on both sides. The experimental results indicate that the channel capacitance is low and therefore signal attenuation is low. The mesh plates with fabric in between behave like a capacitor as a change in distance between the plate and fabric results in a change in signal amplitude. The demodulator output shows that data has been received correctly.

Acknowledgement

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5 References

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