Evaluation of Body-Worn FPCBs with Bluetooth Low Energy, Capacitive Touch, and Resistive Flex Sensing

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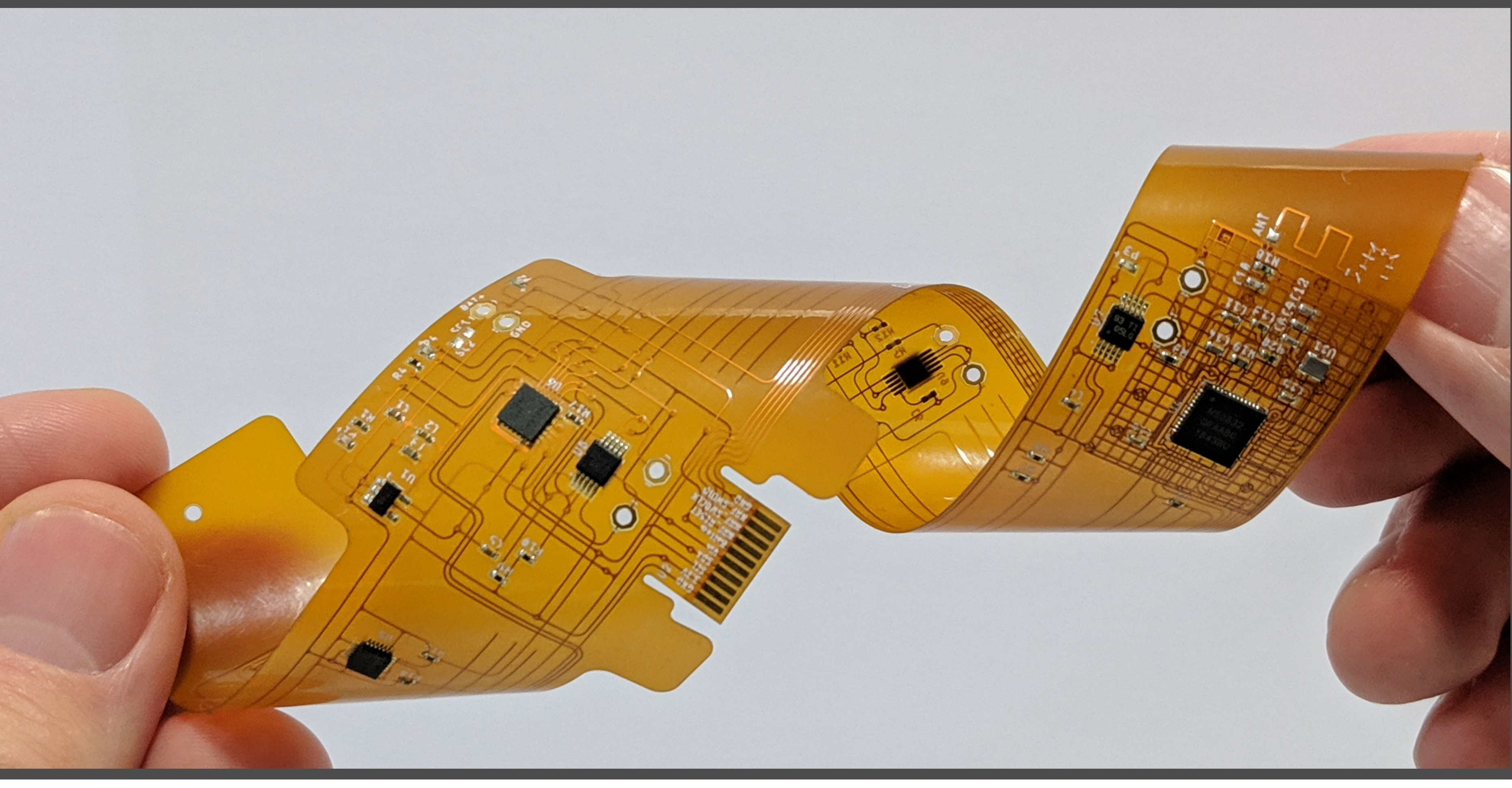
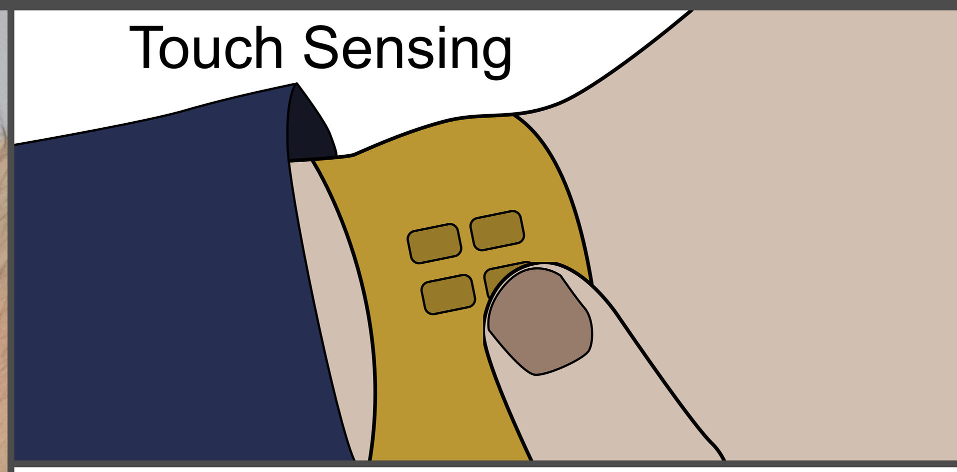
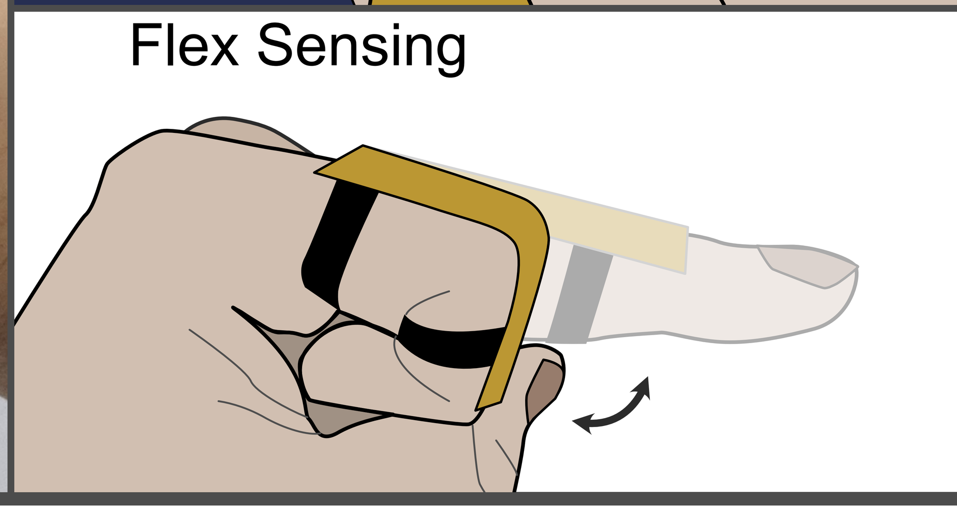




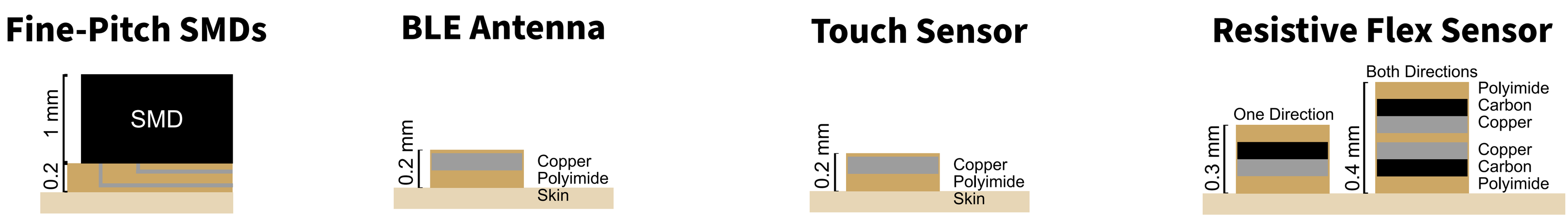


Body-Worn FPCBs

Commercially available flexible printed circuit boards (FPCBs) have the potential to embed electronics, connectivity, and interactivity into the same surface. This makes them an ideal platform for untethered and interactive wearable devices.

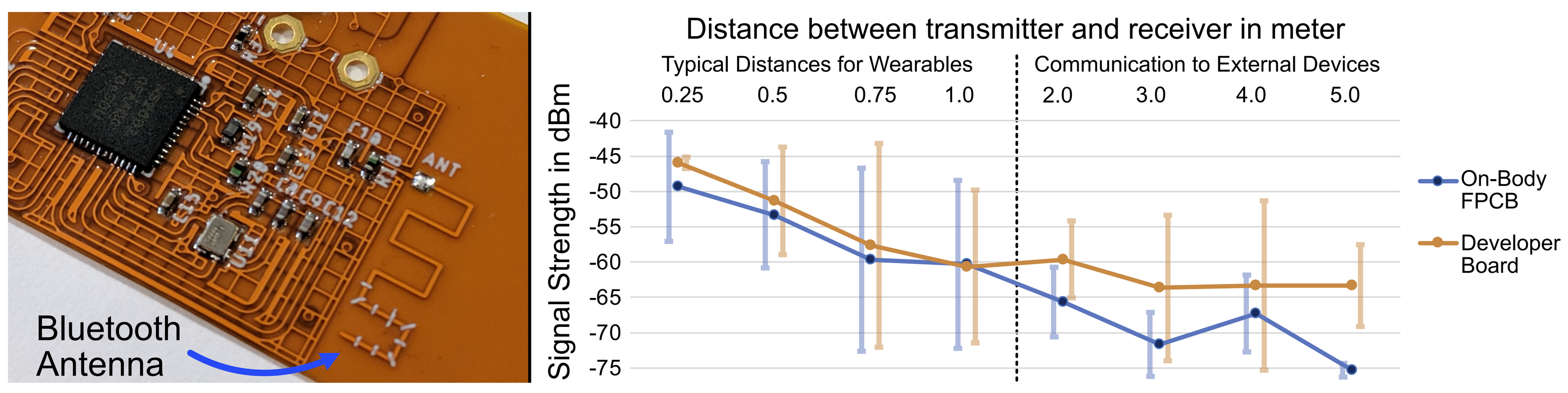
This work contributes towards an understanding of on-body FPCBs by evaluating Bluetooth Low Energy, touch and flex sensing.

Cross-Section of the evaluated FPCBs



Bluetooth Low Energy

FPCBs have different properties than rigid PCBs and are slightly curved when worn on the body. We evaluated their signal strength and compare it to a rigid off-body nRF52832 developer board.

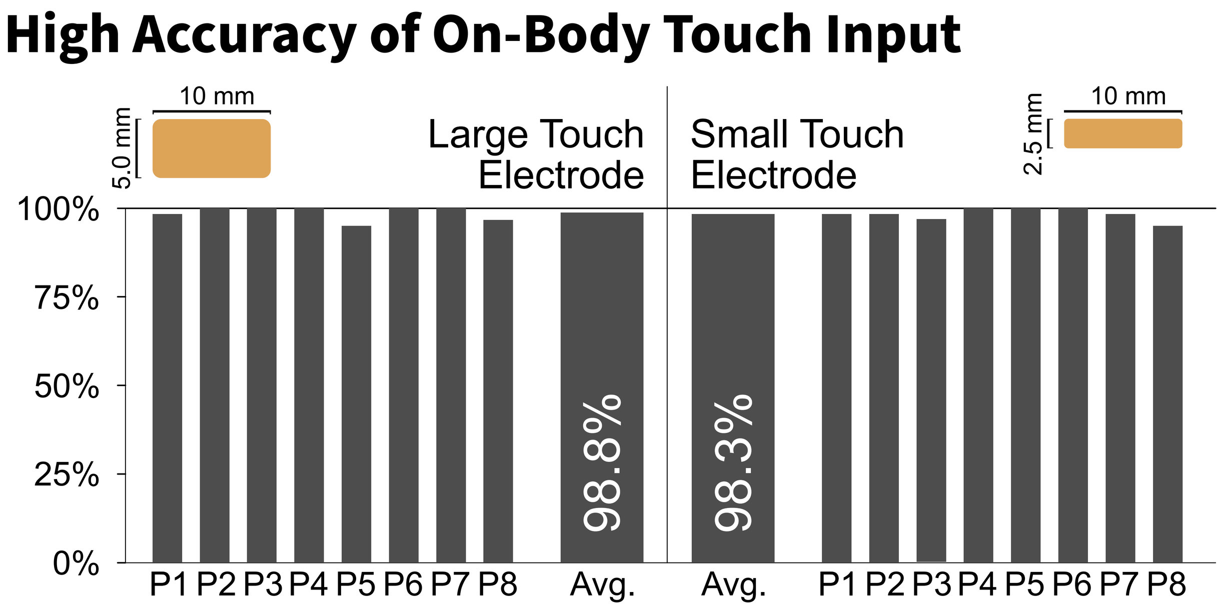


The signal from the FPCB is on average -4.6 dBm lower (-1.8 dBm for 25–100cm). It is still above the Bluetooth 5.0 specification, which requires a *minimum* receiver sensitivity of -70 to -82 dBm.

Capacitive Touch Sensing

Eight voluntary participants (5m/3f) were wearing a touch sensor on their wrist. We tested a large and a small touch electrode with the shape of a rounded rectangle. Each electrode was touched 60 times per participant in a 2.5s interval.

High Accuracy of On-Body Touch Input



Signal-to-Noise Ratio

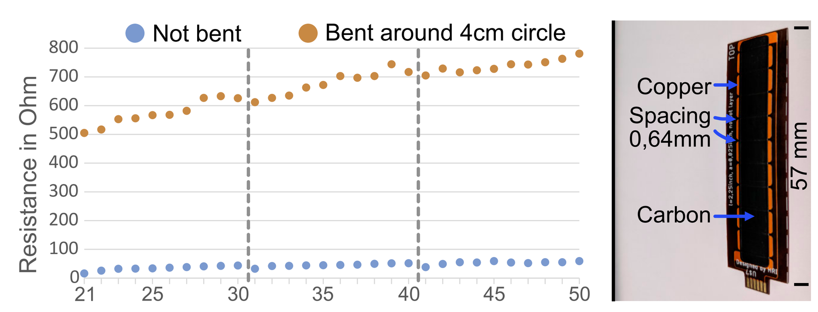
For all participants the SNR was higher than the recommended minimum (~15). On average it was **166.0** (SD=100.5) for the large and **92.7** (SD=56.1) for the small sensor.

Resistive Flex Sensing

We designed a resistive flex sensor using commercially available Carbon-ink that can be fully assembled by FPCB companies.

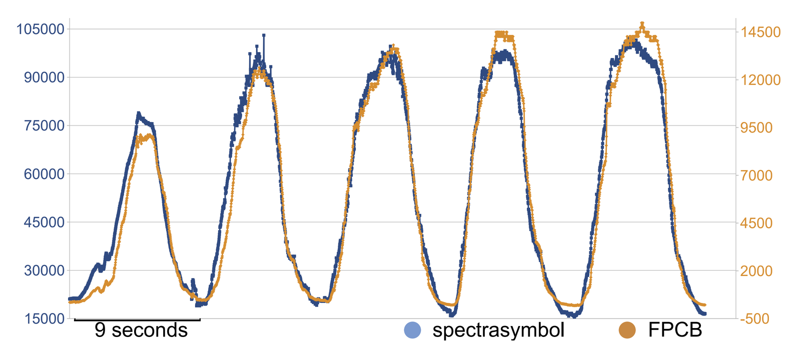
Repeatability

Bending the sensor over a cylinder (Ø=4cm) demonstrates that the flat and the bent state can be easily distinguished. However, the resistance increases over time.



Accuracy Compared to Commercial Sensor

We compared the FPCB sensor to a state-of-the-art flex sensor from spectrasymbol. Both sensors show a smooth increase in resistance when the sensor is bent and a decrease in resistance when the sensor is flattened.



The FPCB sensor has a good repeatability and accuracy. However, their resistance during bending increases multiple iterations.
We recommend the resistive flex sensors for infrequent operations or binary inputs where a precise angular measurement is not necessary.

Taken together, our results demonstrate a high usability of FPCB-based wearable devices that can enable novel prototypes and user studies.

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