LONGECG— Integration of Low-power Sensors in a Textile

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Actual portable bio signals health monitoring solutions are not wearable in the modern sense, i.e., like usual clothes. Clinical measurements such as ECG (Electrocardiograph) require numerous electrodes. Moreover, according to a panel of consulted doctors, many patients would benefit from daily long-term monitoring. Unfortunately, the available solutions able to acquire medical ECG are far from being adapted to such a daily use. Therefore, there is a corresponding lack in the prevention of heart illnesses due to limited observability for reasons such as comfort and usability, and, more importantly, because of the disagreements and irritations due to the long-term use of adhesive gel electrodes and straps. CSEM developed the technology of 'cooperative sensor' to address the integration of sensors with dry electrodes in garments and is further pushing toward system integration into textiles. This paper presents the ongoing activities and the expected achievements to be obtained through the realization of a first demonstrator that will be available in 2020 for first testing.

The diagnosis of different heart conditions (*e.g.*, arrhythmias and other conduction abnormalities) requires long-term monitoring of the electrical activity of the cardiovascular system with an ambulatory electrocardiogram (ECG) device, so-called Holter devices. To capture a complete image of the health state of the heart, in particular in the attempt to capture rare and fleeting events, ECGs should be recorded for periods as long as possible (weeks to months). In recent years, a number of miniature Holter devices has been brought to the market that are relatively simple to use but have only a limited number of leads and, more importantly, are not comfortable to wear over long periods, mainly due to the adhesive of the gel electrodes and straps, the cables to the electrodes, the resulting handling and maintenance, and the weight and size of the electronics.

Consequently, CSEM is developing a 12-lead Holter monitor comfortable to wear even during long periods. In contrast to most other ambulatory ECG recorders (including patches), dry, adhesive-free active electrodes are used and integrated in a tight-fitting vest together with the electronics. To achieve this, the system is built via CSEM's patented cooperative-sensor technology that allows connecting a large number of active electrodes only with a 1-wire bus while preserving ECG signal quality at least to the level of conventional devices. With respect to previous developments, the wearing comfort is further enhanced by reducing the size and the weight of the cooperative sensors thanks to an ultra-low-power ASIC. This allows, for the first time, to power the active electrodes of the cooperative sensors remotely via the same 1-wire bus used for the measurement of ECG. The current return is achieved by the body itself. Even though the wire needs to be insulated for correct operation, a failure of insulation due for instance to tear and wear or to the presence of body fluid (*e.g.*, sweat) is safe since the powering current is limited to a value below the maximum allowed by the medical standard IEC 60601-1. The vest is washed together with its embedded sensors — only the recorder and its battery have to be removed. A high wearing comfort of the sensor garment is finally achieved by using recent technologies from the sport textile industry.

The ASIC is housed in each of the sensors (see Figure 1) and is optimized for ultra-low power and for meeting the best ECG signal quality compatible with medical use, in particular in motion and in environments disturbed with electromagnetic noise. The ASIC includes the following building blocks: (a) a power-management unit responsible for harvesting power from the recorder and for providing a clean power supply to the other circuits of the ASIC; (b) a low-noise wideband unity-gain buffer to address the high-impedance contact with the skin; and (c) a digital logic for sensor synchronization and time-sharing. Up to 10 sensors are embedded in the textile garment (see Figure 1).

The textile garment has to fulfill three major functions: 1) it shall connect the sensors and the recorder via a 1-wire bus; 2) it shall apply the sensors with slight pressure on the skin at defined spots; and 3) it shall be comfortable to wear. To achieve these objectives, we are working with sport fashion designers on a highly stretchable seamless apparel with printed conductive tracks. An additional challenge comes from the fact that body shapes vary a lot from one person to another. Since the positioning of the sensors and their skin contact is of high importance, easily adaptable garments are developed, to which healthcare professionals can attach the sensors so that their positions and preload can easily be custom-fitted to any body type. The drawing shown in Figure 1 depicts a solution based on a wrapping garment with a freely adjustable waist circumference. Moreover, as the cooperative sensors have only one connection to the 1-wire bus, printed conductive pads on the vest allow healthcare professionals to freely pin the sensors to the right spots and thereby achieving fine adjustment of electrode position.

Figure 1: Drawing of the developed vest showing the sensors, conductive tracks, and pads allowing custom fine positioning of the electrodes as well as the ASIC embedded in the cooperative sensors.

In conclusion, this development brings textile solutions and electronics integration to achieve usability and comfort for the long-term measurement of ECG of outpatients.