Unobtrusive and Non-invasive Physiological Monitoring

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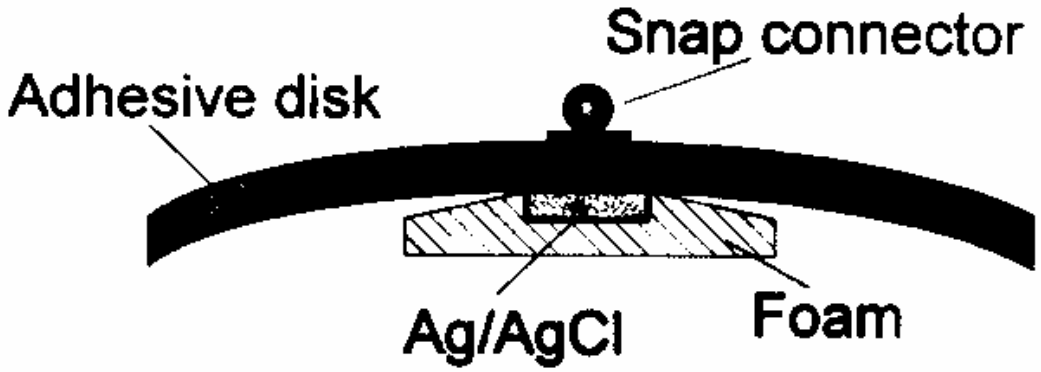
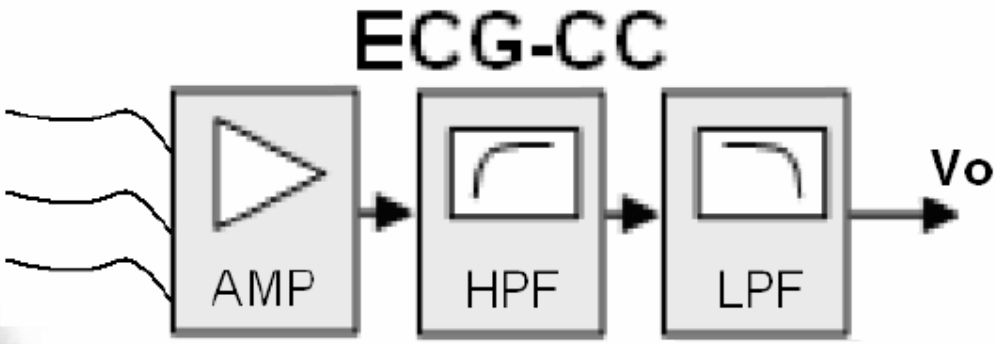
Wet electrode: Silver/Silver chloride (Ag/AgCl) electrode



Dry electrodes

- Impedance transformation at sensing site
- Metallic, polymer or e-textile surface in direct contact with body

T-shirt smart textile electrodes



Requires a high impedance instrumentation amplifier

Micromachined dry electrode

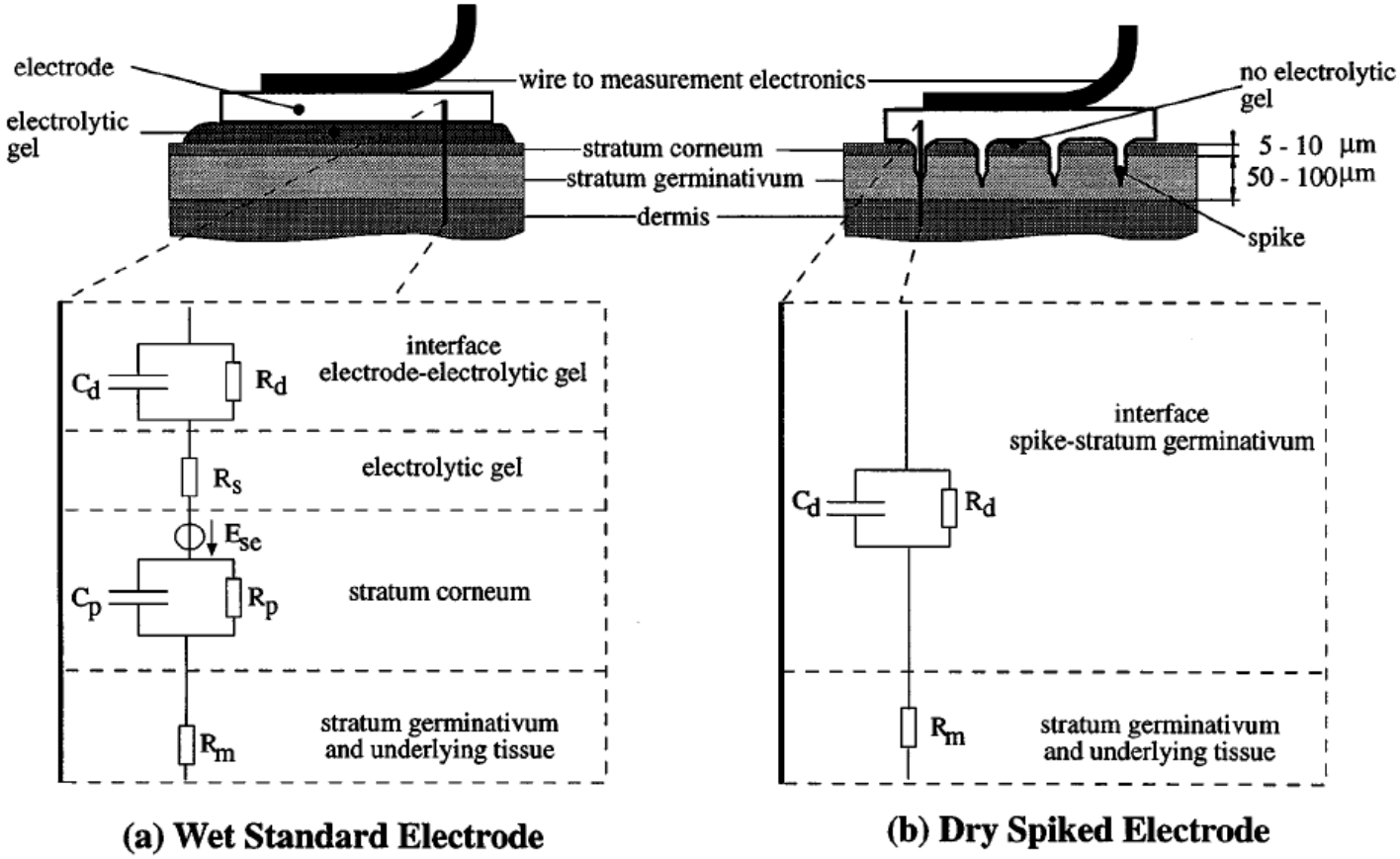
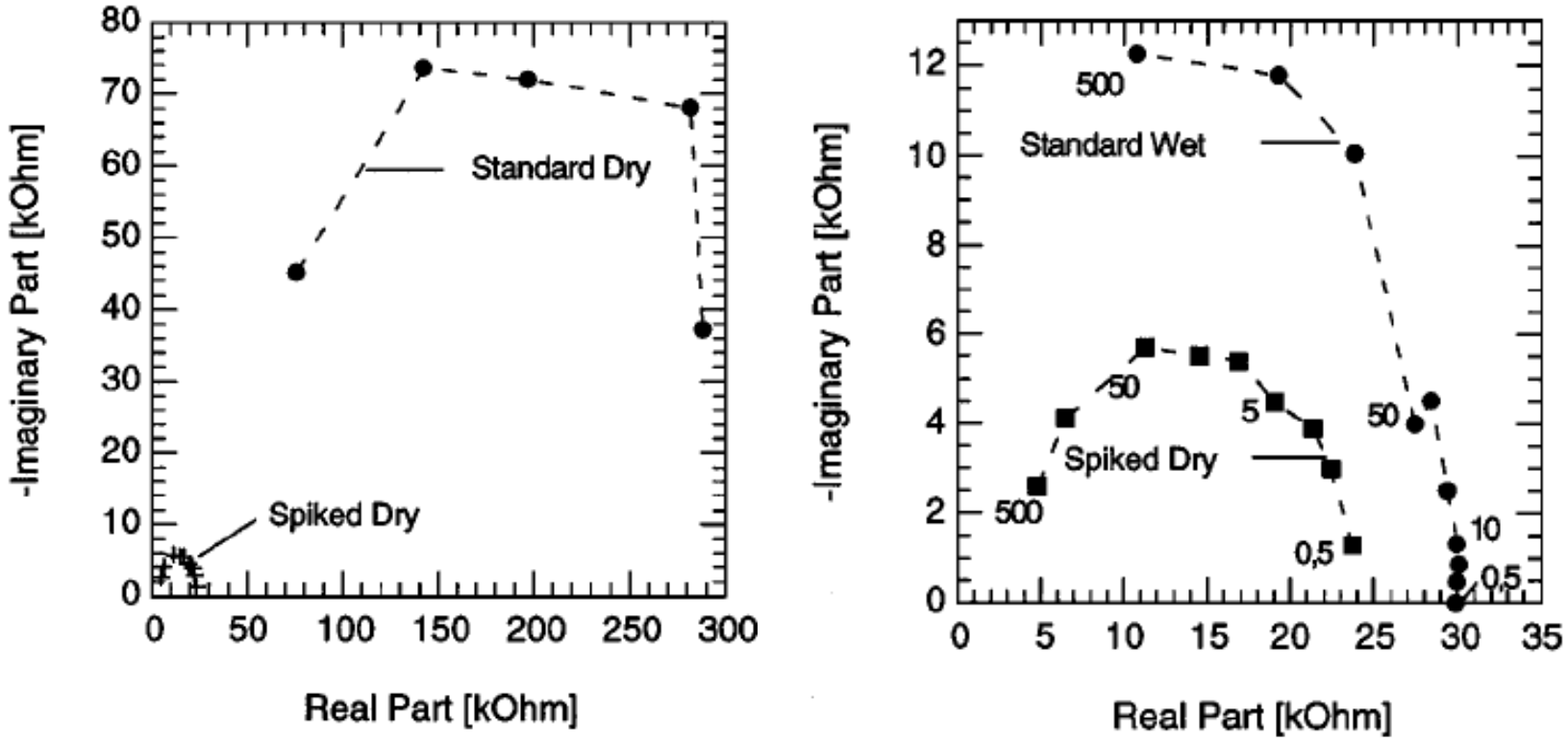


Fig. 1. Comparison of the presented spiked electrode (b) with a standard electrode (a). (a)Electrolytic gel is needed to overcome the isolating characteristic of the *SC*. (b)The spikes penetrate into the electrically conducting *SG* to sense biopotentials. Note that for a dry spiked electrode the electrical model is less complex compared to a wet standard electrode. This is mainly due to the fact that in (b), the spikes create a direct interface with the *SG*, thereby circumventing the influence of the electrolytic gel and the *SC*.

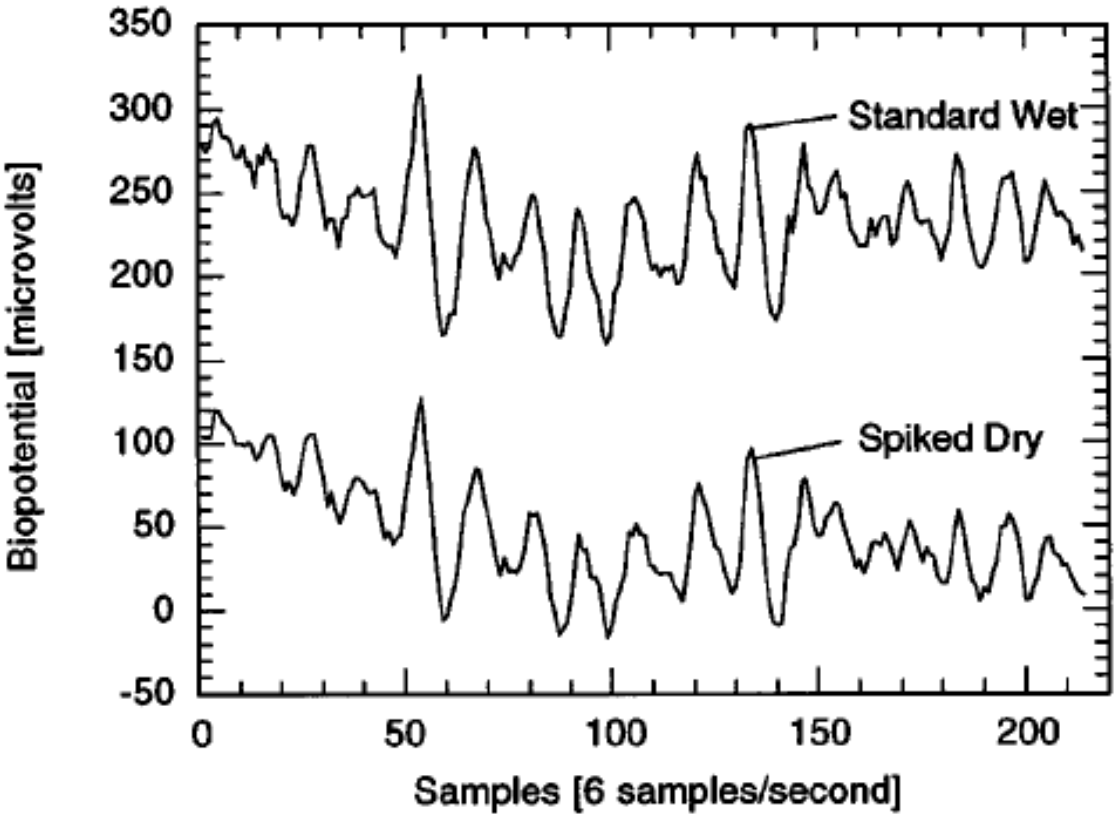
Gris et al, IEEE Trans. BME, 2001

Nyquist plot of micromachined dry electrode



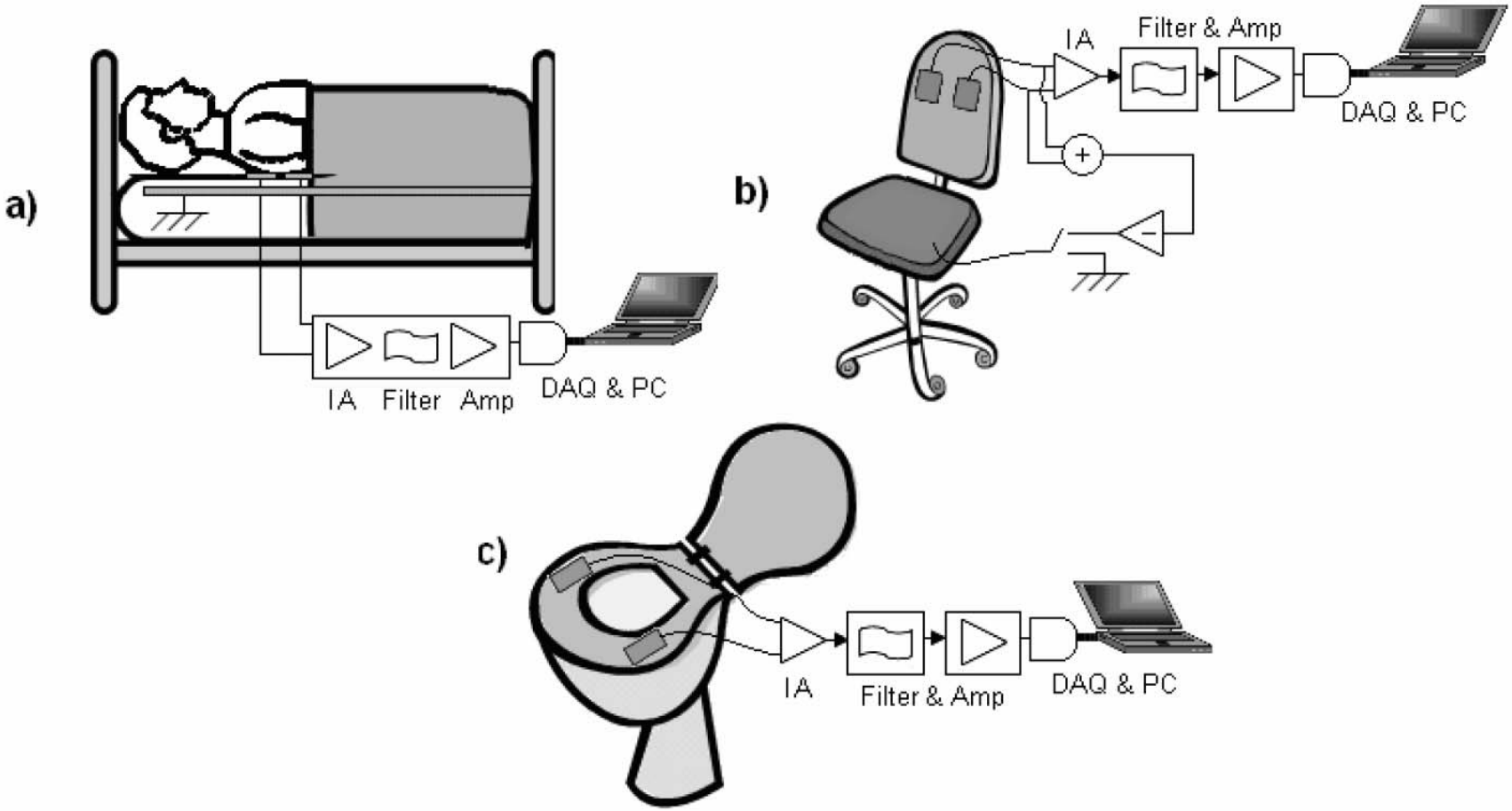
Gris et al, IEEE Trans. BME, 2001

Comparison of EEG raw data recorded by a dry spiked electrode and a wet standard electrode

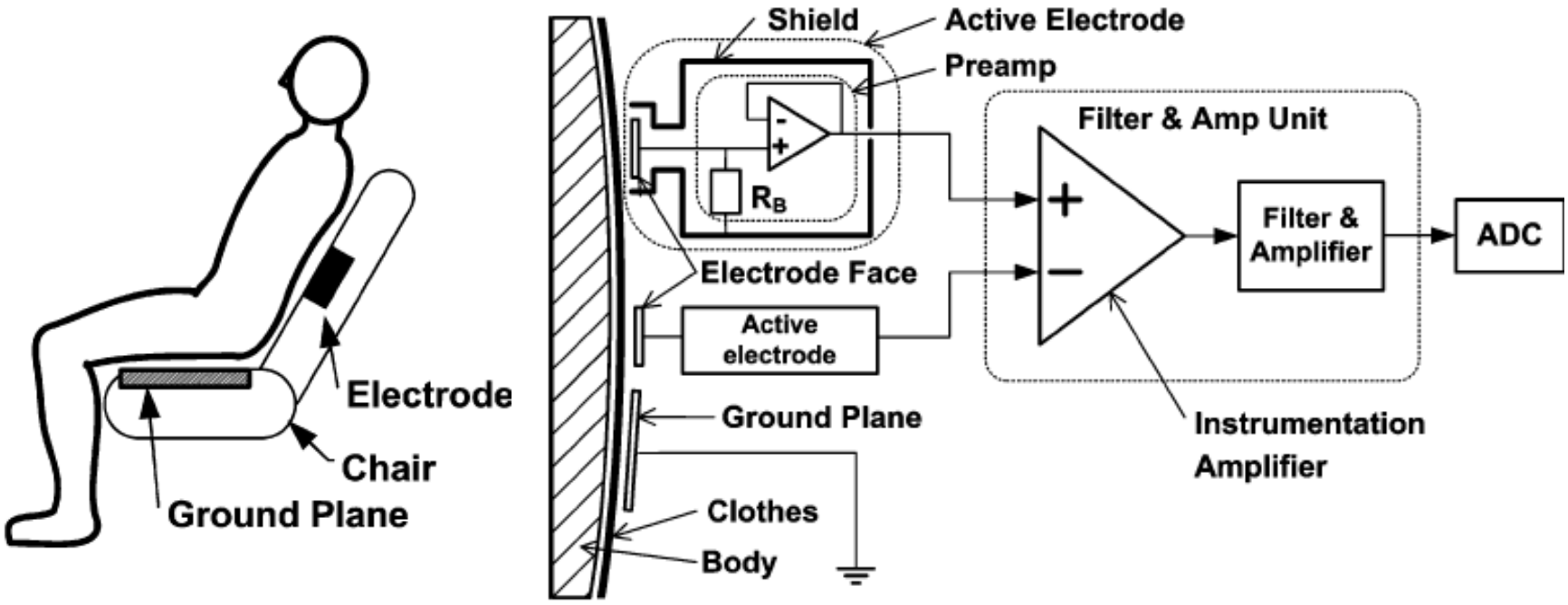


Gris et al, IEEE Trans. BME, 2001

Unobtrusive ECG monitoring based on capacitive-coupled electrode



ECG measurement without conductive contact



Lim et al, IEEE Trans. BME, 2006

ECG without conductive contact (cont.)

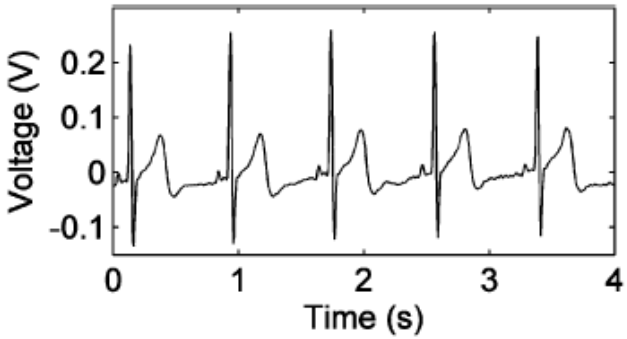


Fig. 6. ECG waveform obtained with conventional Ag–AgCl electrodes attached to the back skin of the same subject as in Fig. 5 (BIOPAC MP150, gain 1000, 0.5 Hz~35 Hz).

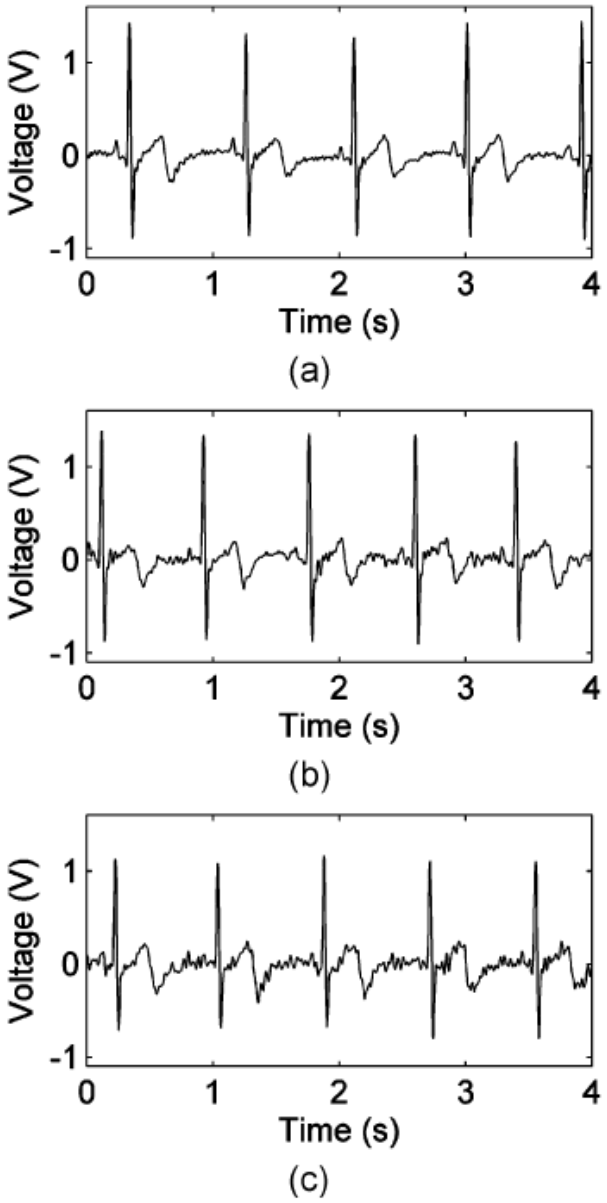
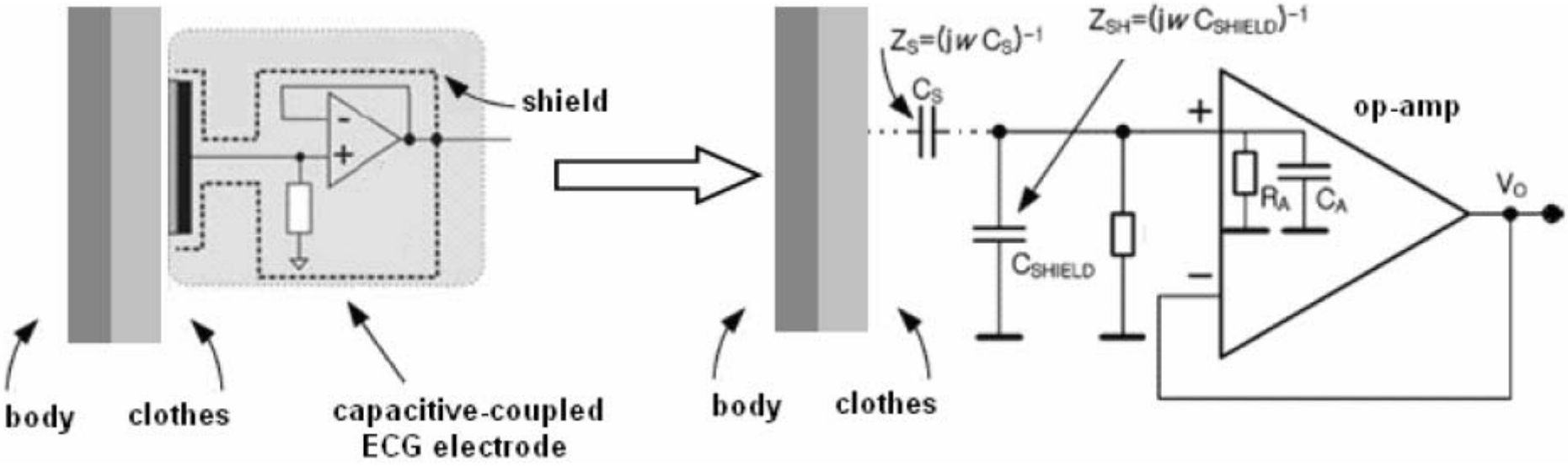


Fig. 5. ECG waveforms obtained by the presented method; (a) through a cotton shirt (twill weave, thickness 0.33 mm, (b) through a woolen business suit (thickness 0.37 mm) over a cotton dress shirt (thickness 0.22 mm), and (c) through a acrylic shirt (twill weave, thickness 0.65 mm). In all cases, the subject wore cotton underwear. Thickness gauge: Mitutoyo 7301.

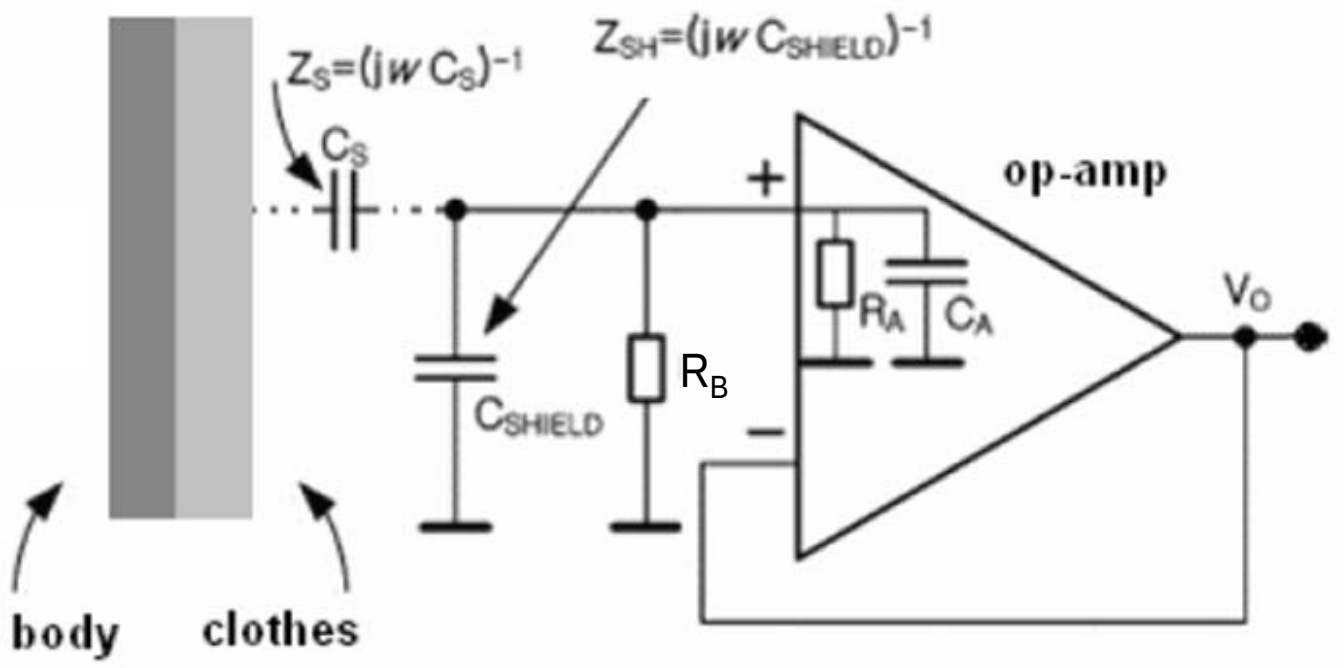
Lim et al, IEEE Trans. BME, 2006

Capacitive-coupled electrodes

- Insulated electrode which is not directly contacted to the body



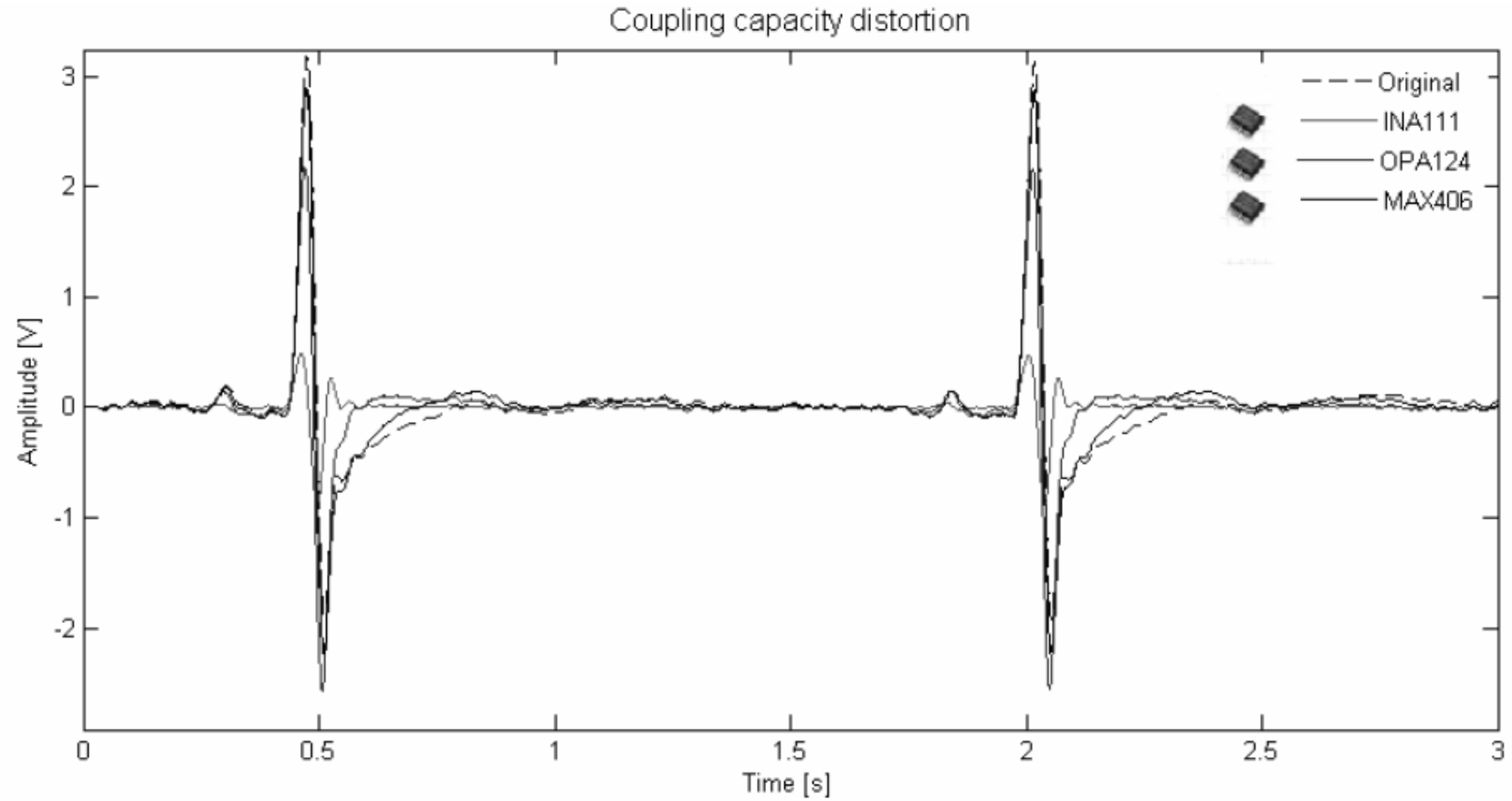
Equivalent electric model



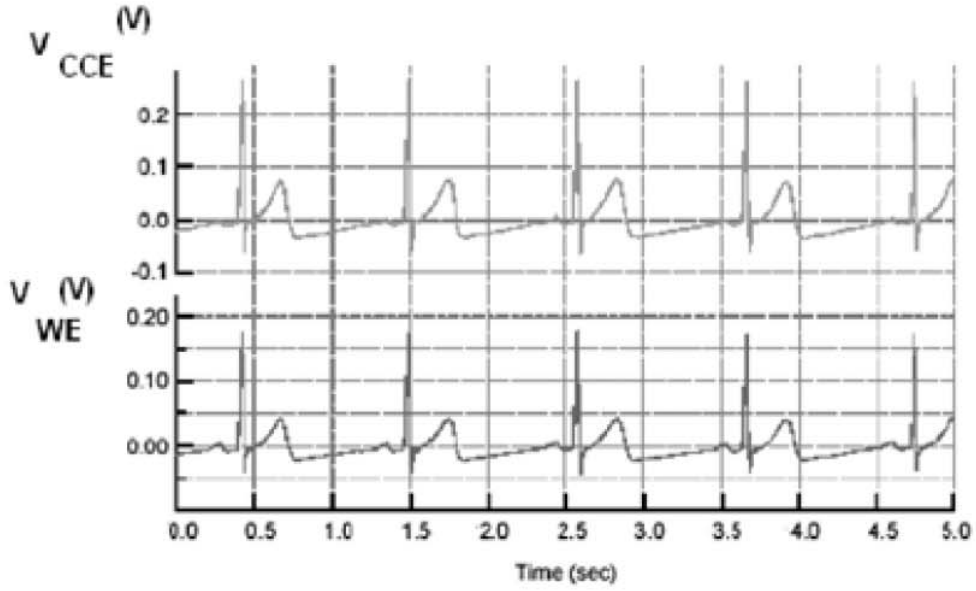
$$Vo(\omega) = \frac{C_S \cdot R_B \cdot j\omega}{1+(C_A + C_{shield} + C_S)R_B \cdot j\omega} \cdot V_{ECG}(\omega)$$

R_B : a resistor for bias current of OP Amp

Vo versus C_S variations for different high input impedance amplifier



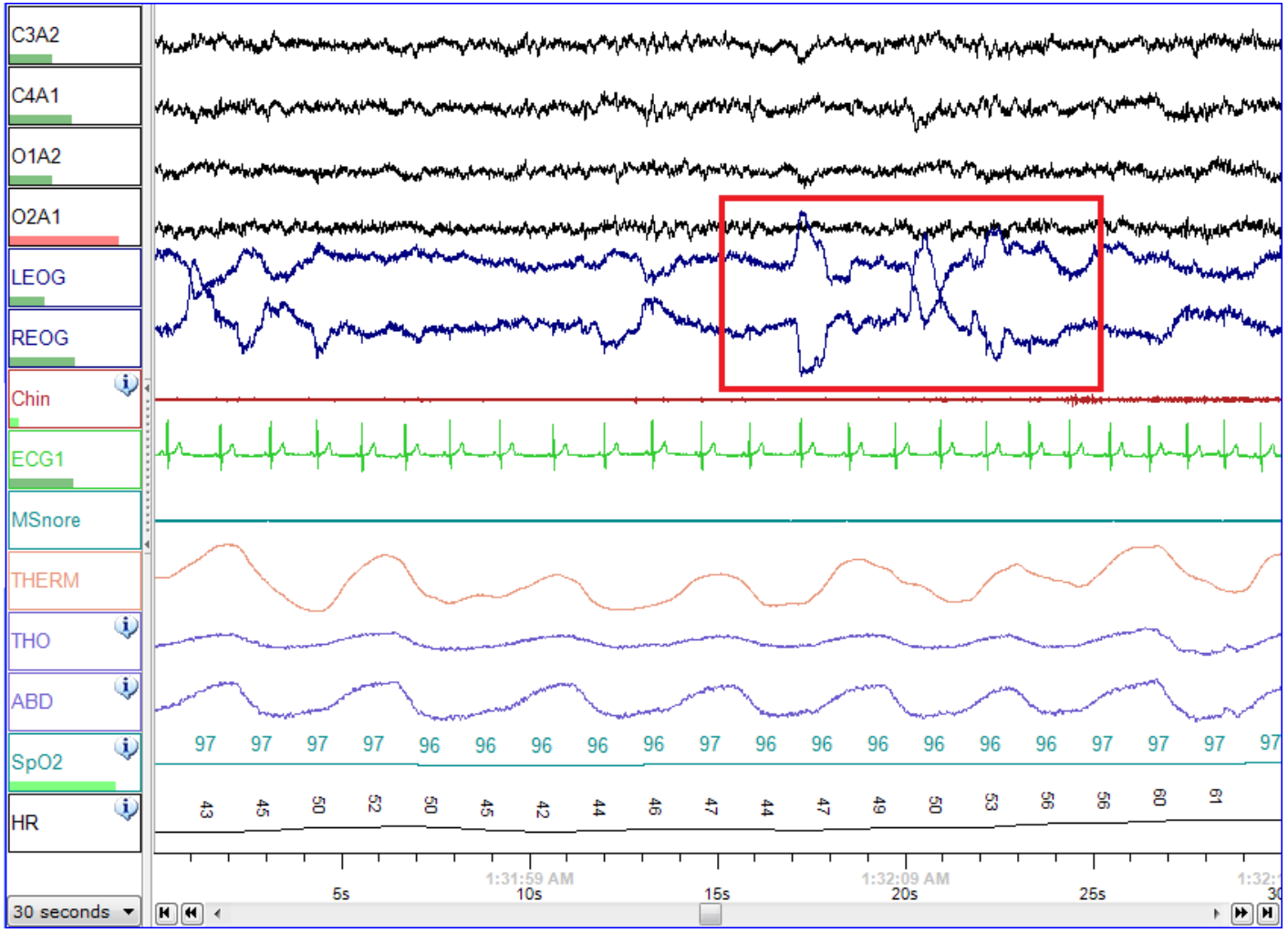
Quasar electrodes



Polysomnography (PSG)

https://zh.wikipedia.org/wiki/

Physiological signals in PSG



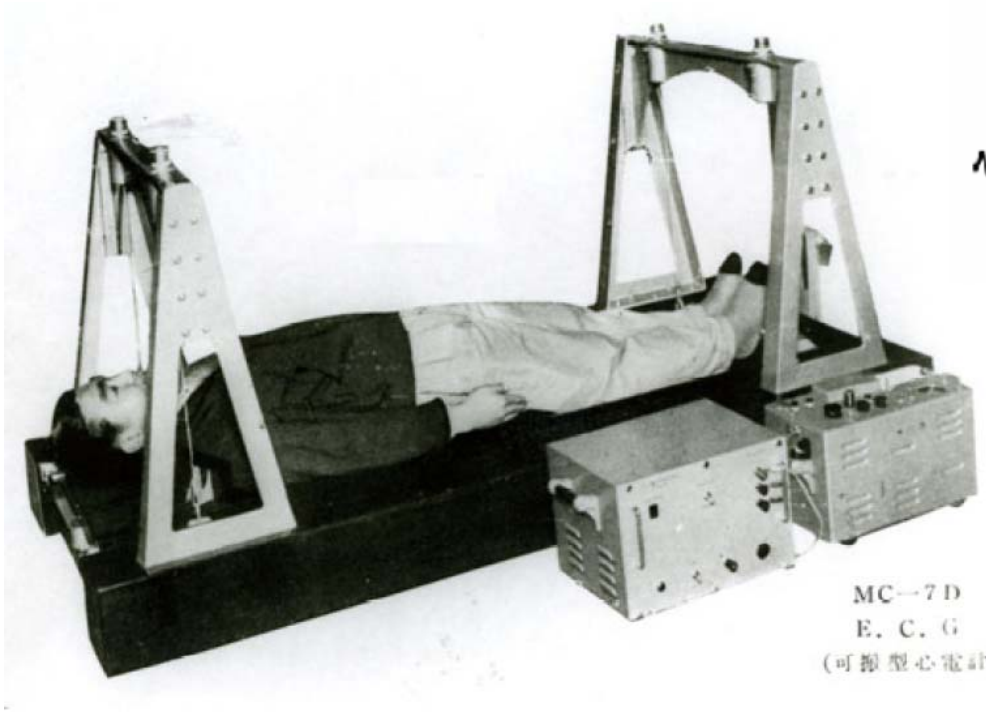
https://zh.wikipedia.org/wiki/

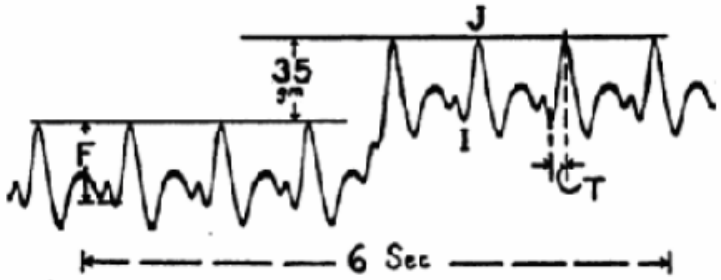
Ballistocardiography

- Measures small movements of the body, imparted by the ballistic forces (recoil and impact) associated with
  - Cardiac contraction
  - Ejection of blood
  - Deceleration of blood flow through the large vessels
- Challenge
  - Low amplitude of the mechanical oscillations caused by cardiac activity comparing with
    - Mechanical oscillations associated with subject breath
    - Artifacts related to the subject motion

Ballistocardiography (cont.)

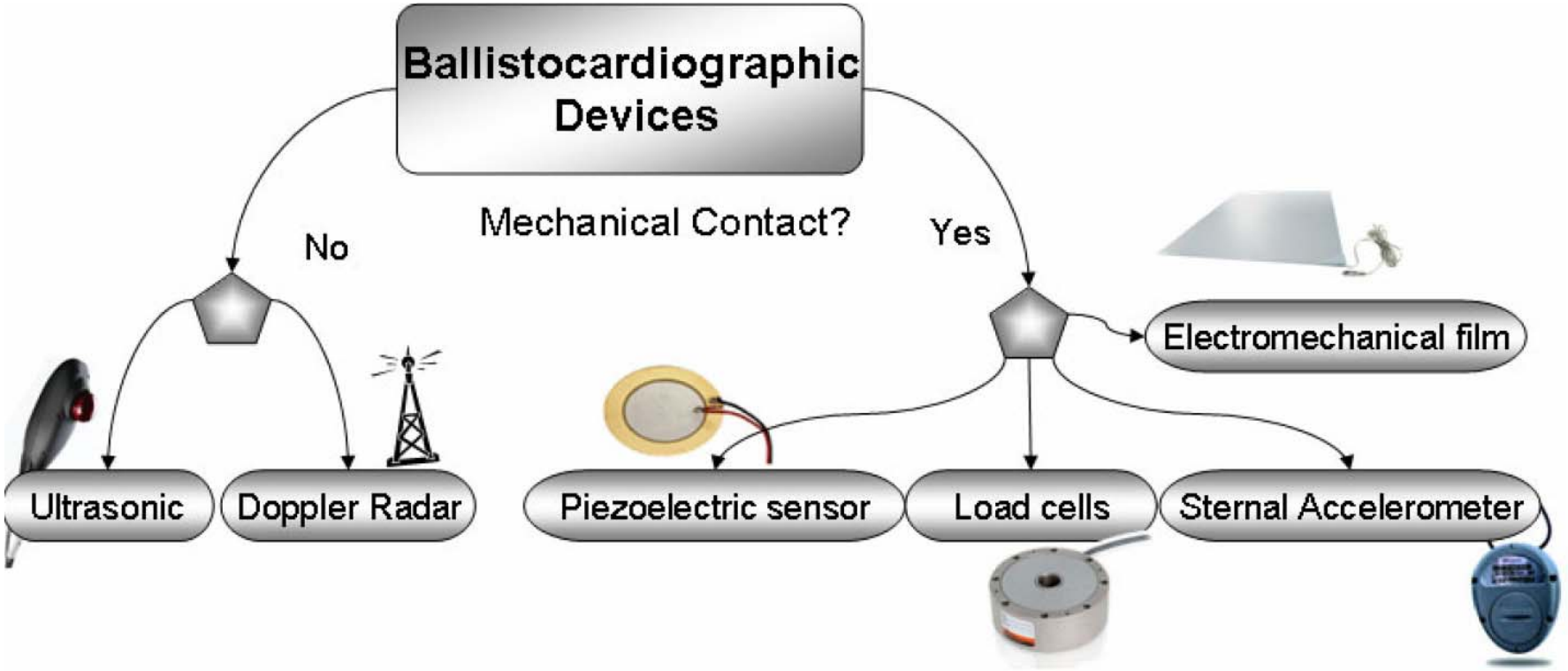
First BCG architectures



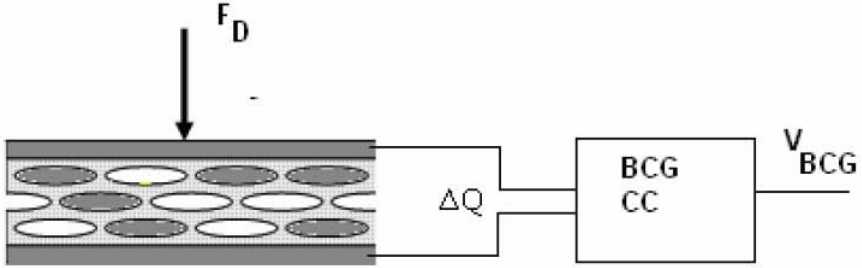


Suspended rigid platforms using elastic ropes

BCG classification

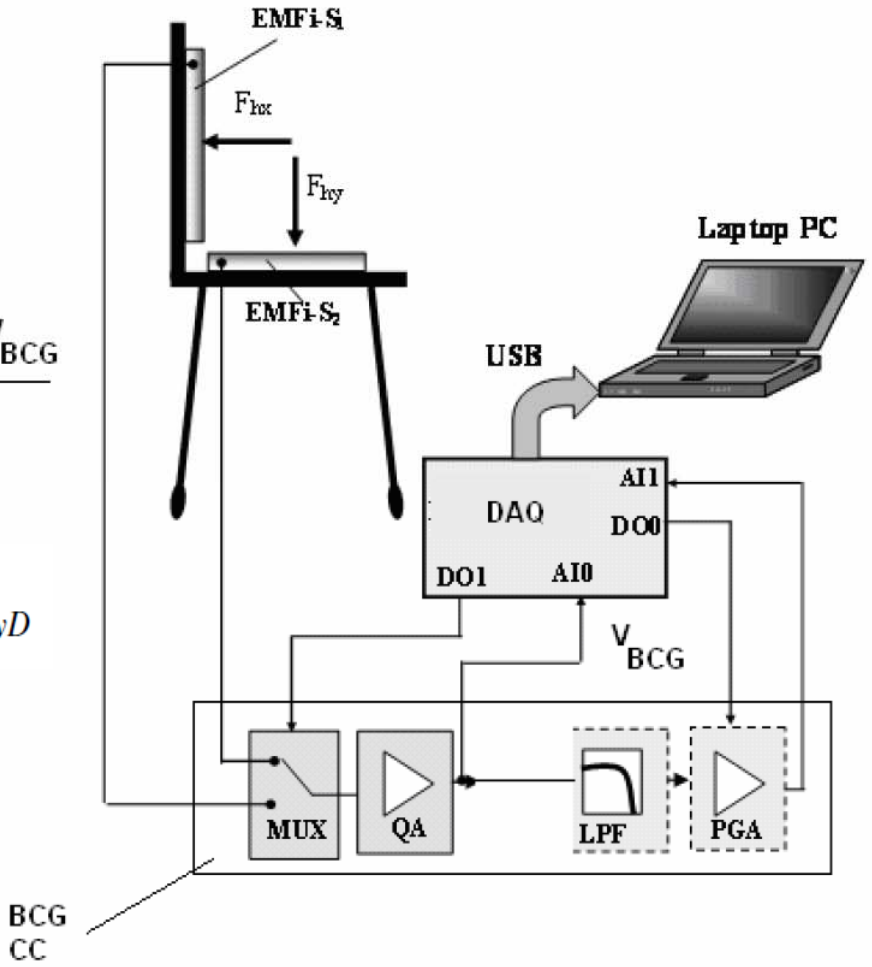


Electromechanical film (EMFi) based system for heart rate and respiratory rate



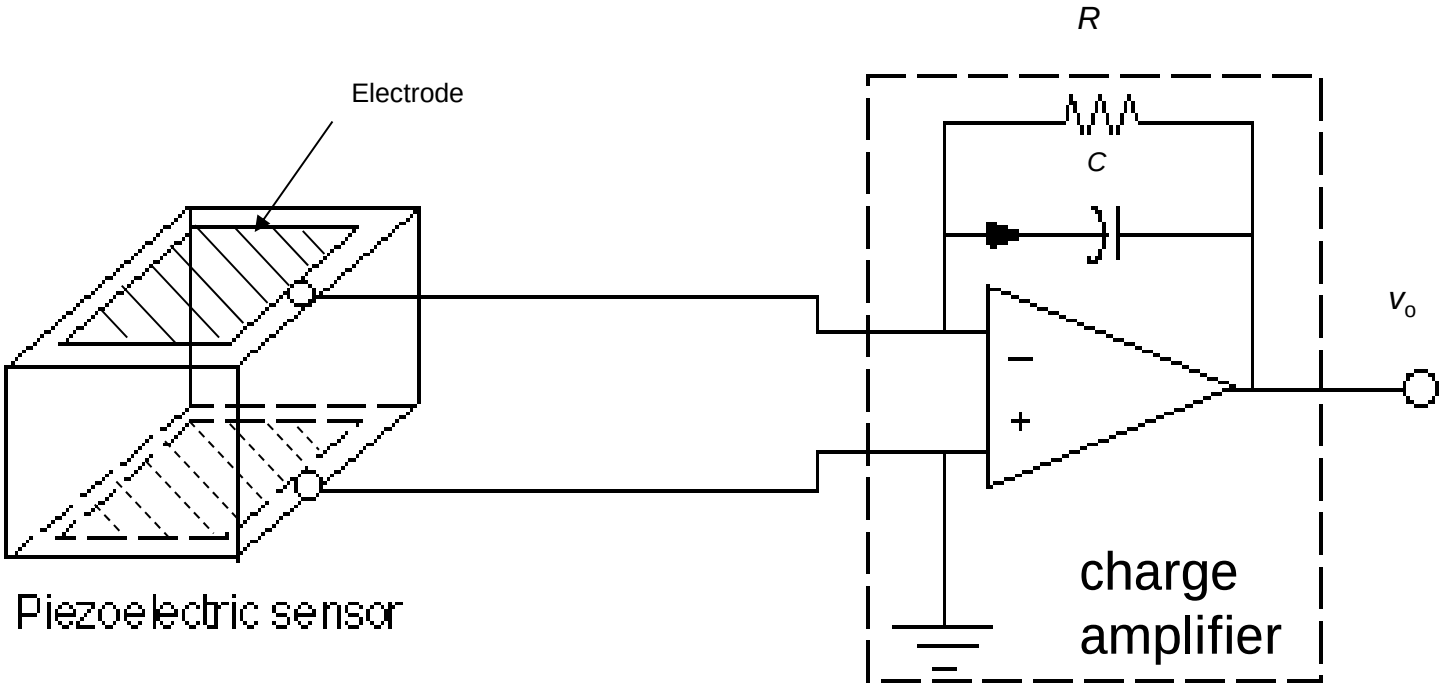
$$F_{hx} = F_{hxS} + F_{hxD} \qquad F_{hy} = F_{hyS} + F_{hyD}$$

$$\Delta Q_x = k \cdot F_{hxD} \qquad \Delta Q_y = k \cdot F_{hyD}$$



Charge amplifier

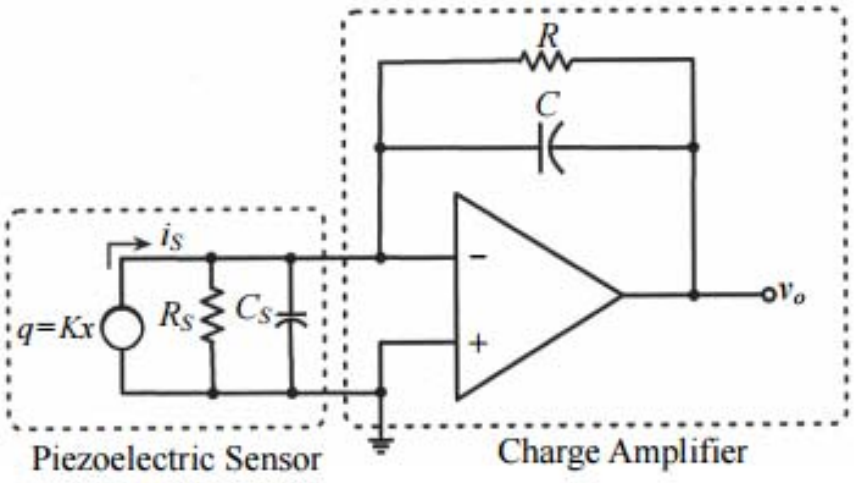
$$v = \frac{1}{C}\int_0^{t_1} i\,dt = \frac{1}{C}\int_0^{t_1} K\frac{dx}{dt}\,dt = K\frac{x}{C}$$



Highpass filtering: passes frequencies higher than the corner frequency $f_c = 1/(2\pi RC)$.

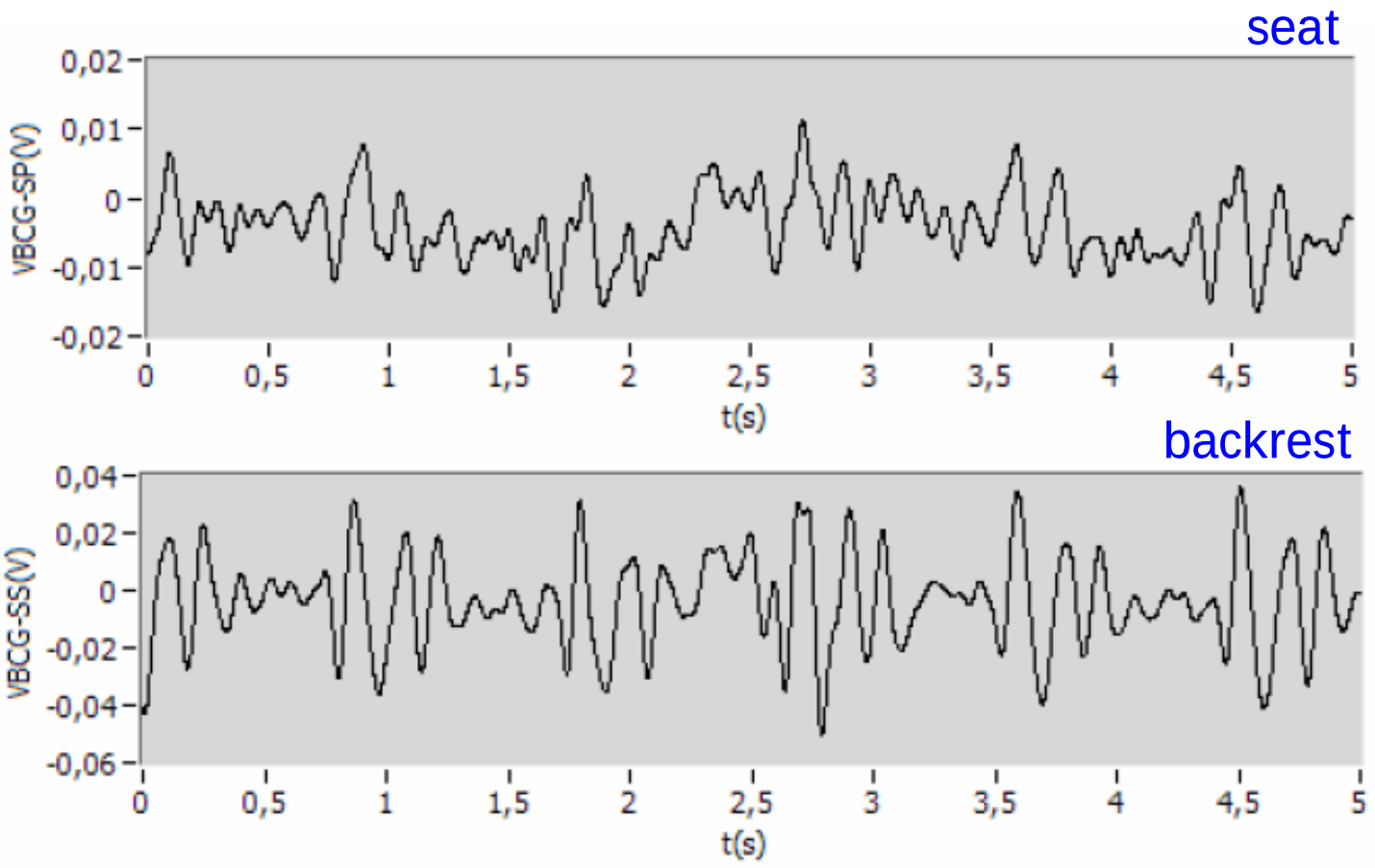
Charge amplifier

- 下圖為某一壓電感測器（Piezoelectric sensor）連接電荷放大器（Charge amplifier） 的等效電路。
- 假設該壓電感測器的靈敏度（Sensitivity） K= 10^{-3} 庫倫/公尺（C/m）。
- 若是利用此感測器量測最低頻率為 1 Hz、最多僅 1 mm 的位移 信號，若欲使電荷放大器的輸出 v_o 最多達 -10 伏特，則此電荷放大器的電阻R和電容 C 應各為多少？（15 分）

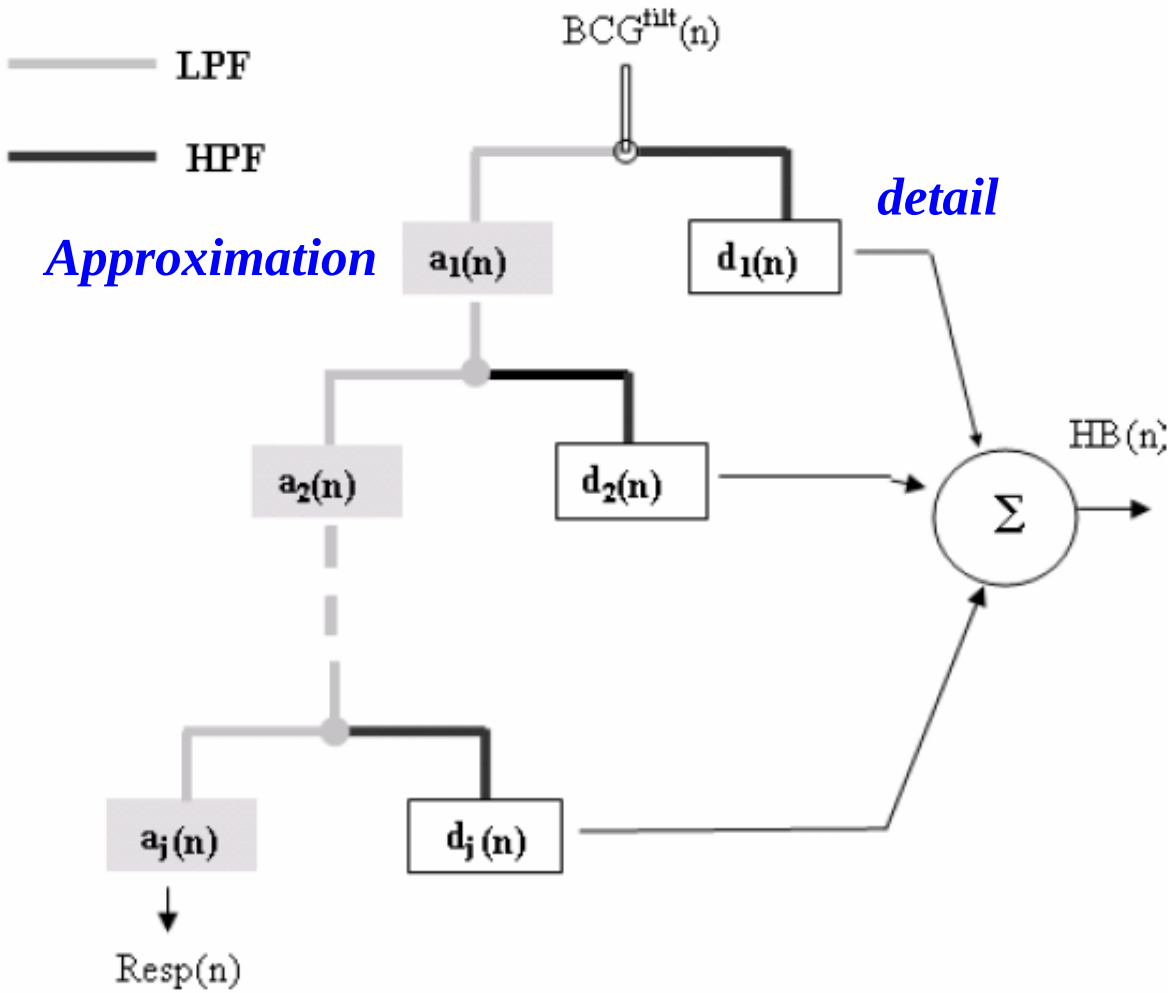


102年高等三級暨普通考高考三級 醫學工程

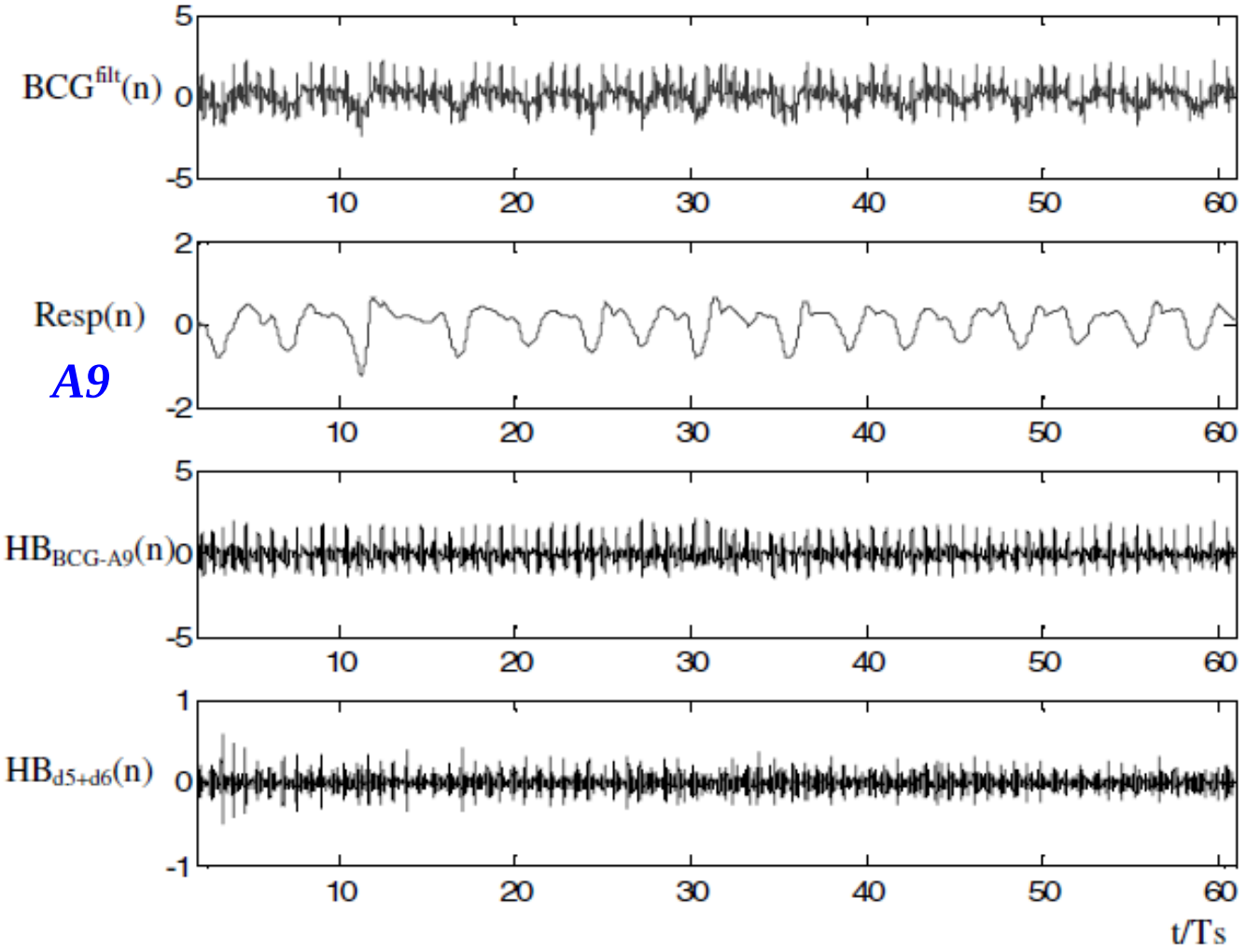
BCG by EMFI sensors placed in the seat and backrest of a chair



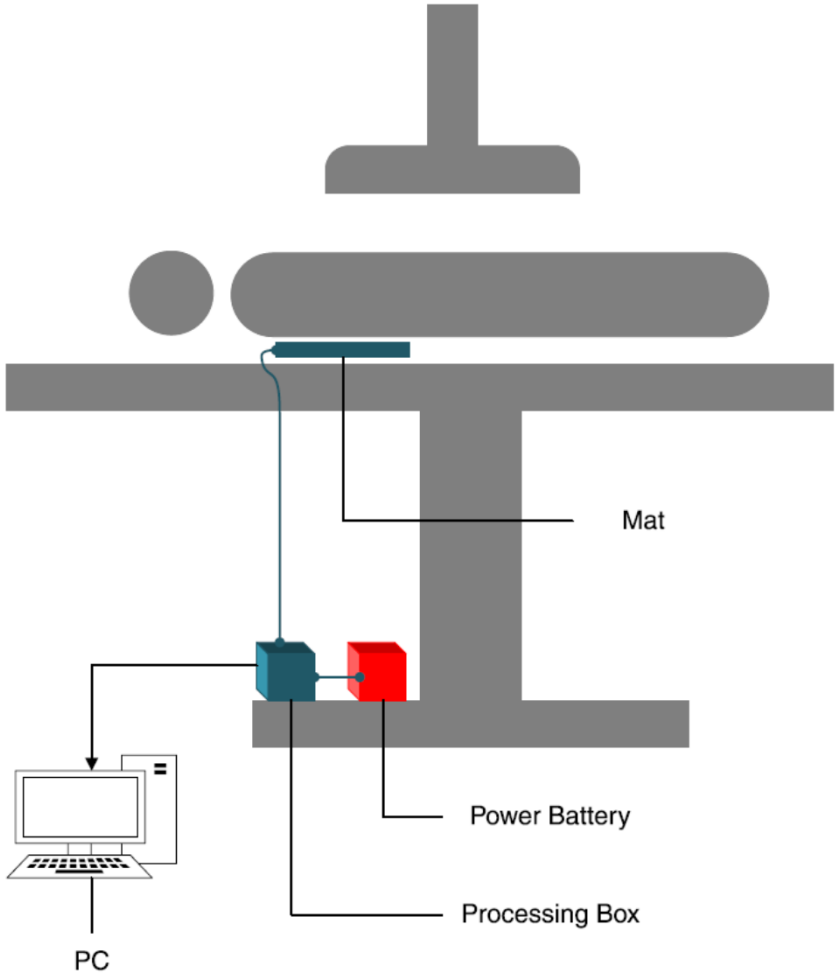
Discrete wavelet transform of BCG

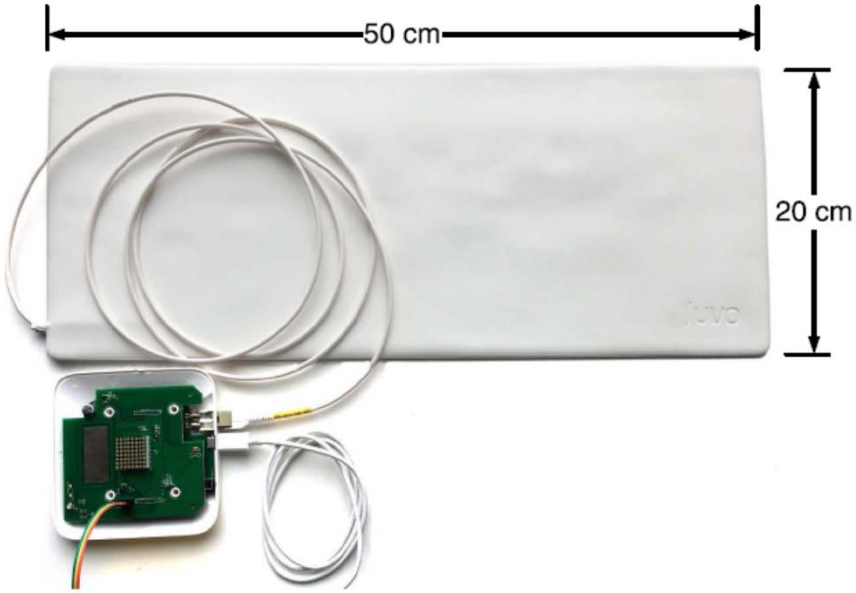


DWT processing of BCG



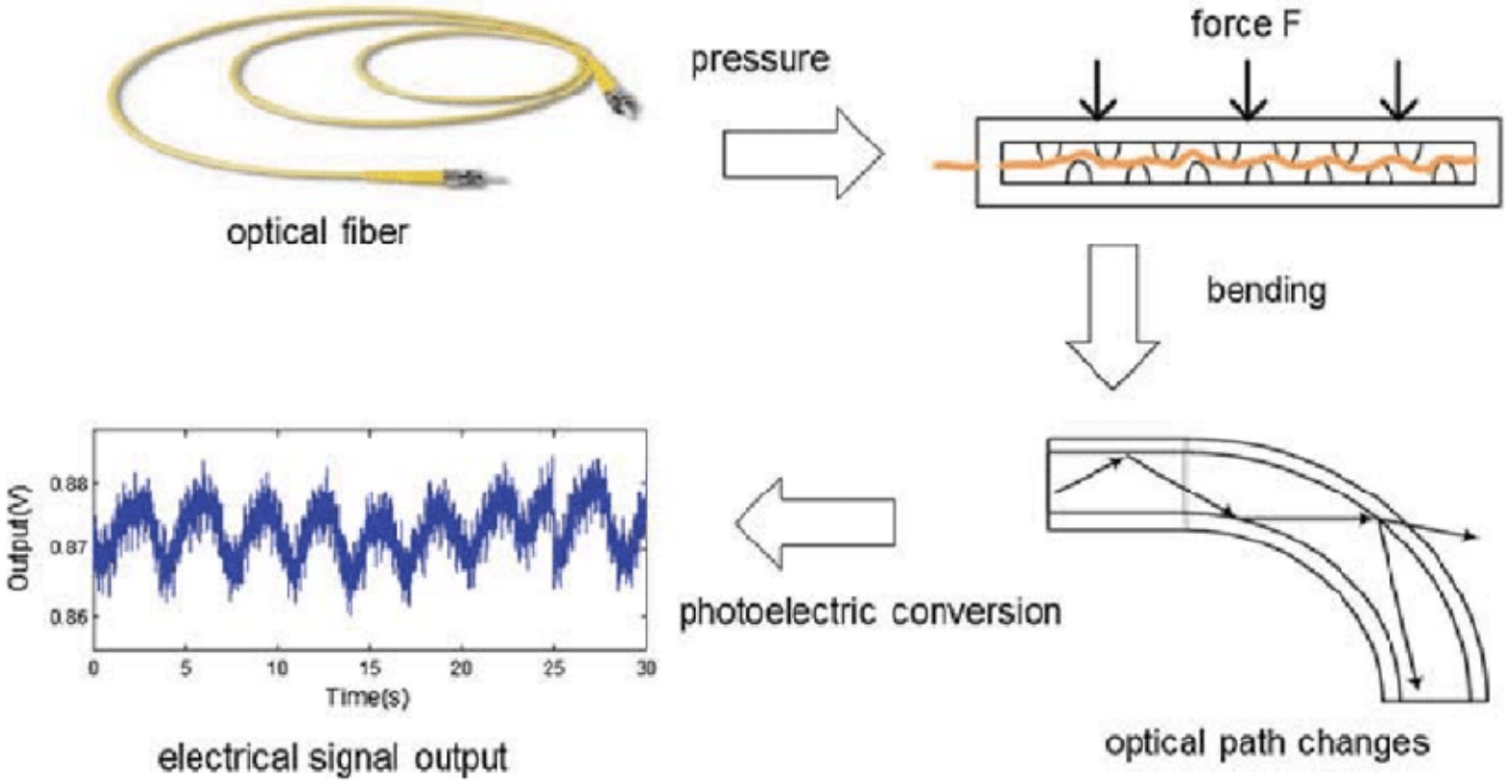
Microbend fiber optic sensor to monitor heart rate and respiration in a nonintrusive manner





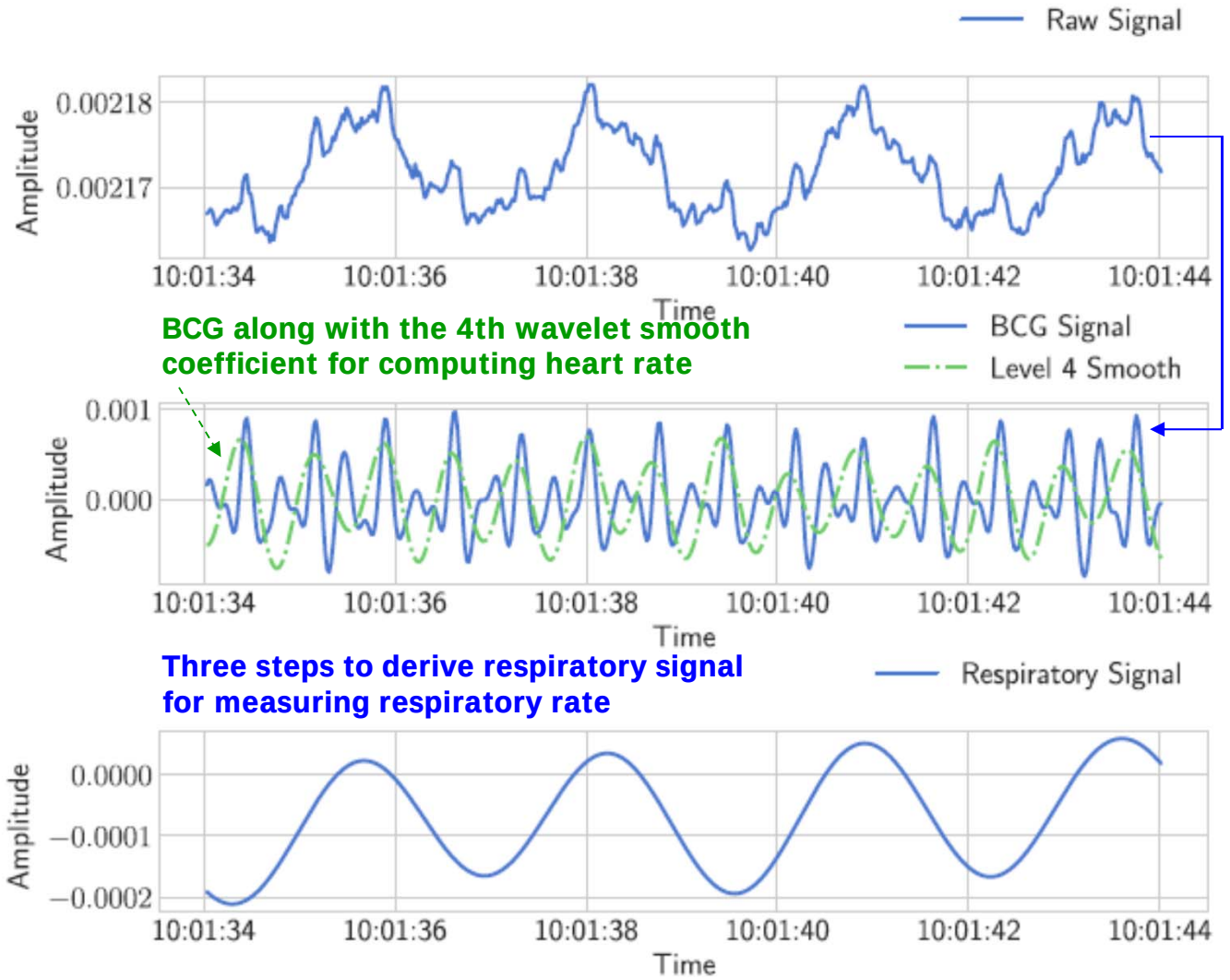
Sadek et al. IEEE Access 6:2506-2514, 2018

Microbend fiber-optic sensor



Liu et al, Apnea detection with microbend fiber-optic sensor, Lecture Notes in Electrical Engineering 2017.

BCG and respiratory signals from fiber optic sensor deformation



Bandpass filter to derive BCG (cutoff frequencies at 0.01Hz - 0.4Hz)

Sadek et al. IEEE Access 6:2506-2514, 2018

Microbend fiber-optic sensor for sleep apnea

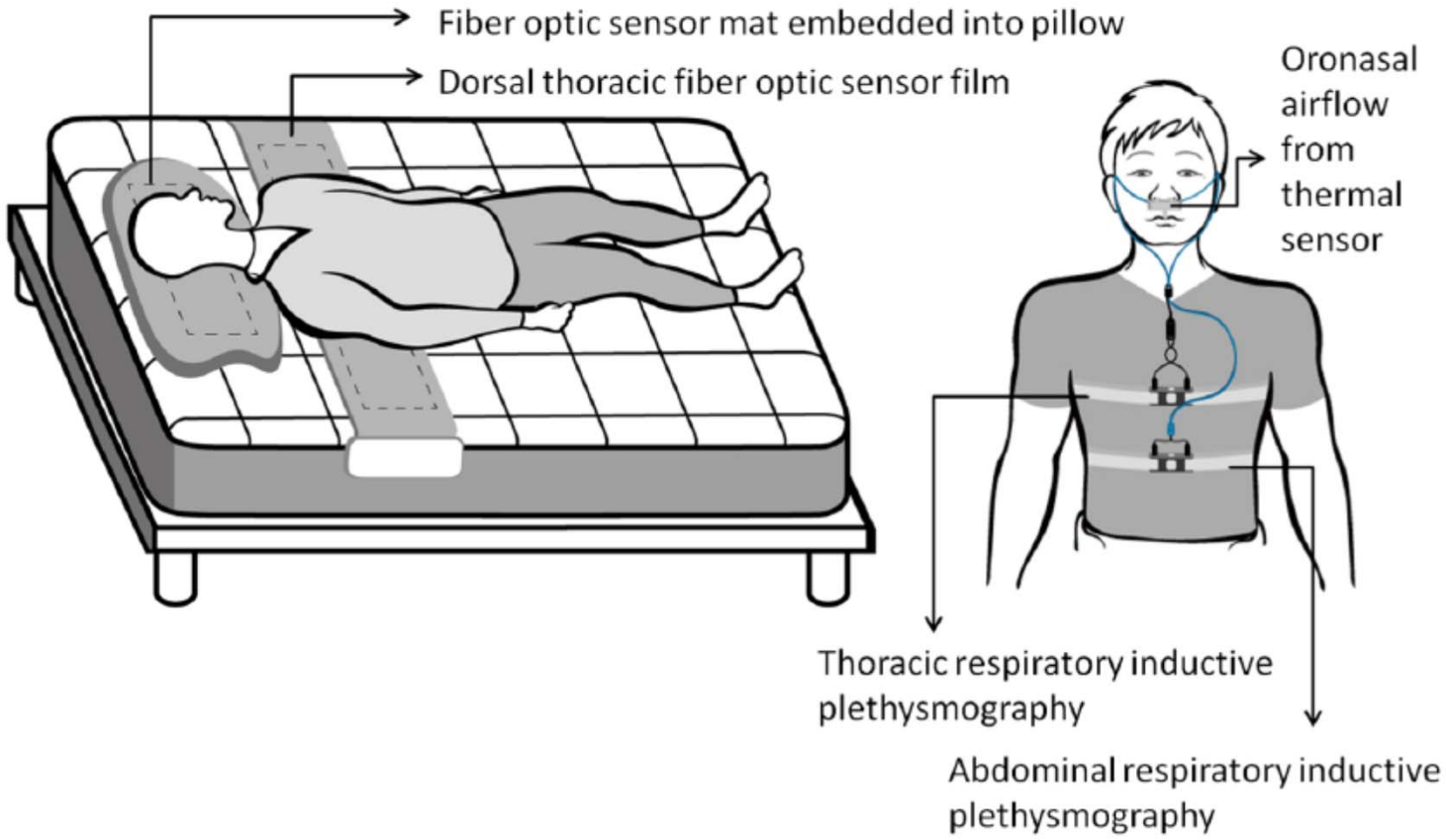


Figure 1. Scheme of physiological measurement for sleep monitoring: two FOSs are placed inside a pillow and under the subject's dorsal thoracic region, respectively. FOS deformations as well as oronasal airflow, thoracic and abdominal wall movements are recorded simultaneously in a PSG system.

Hsu et al. Physiological Measurement 40:075005, 2019

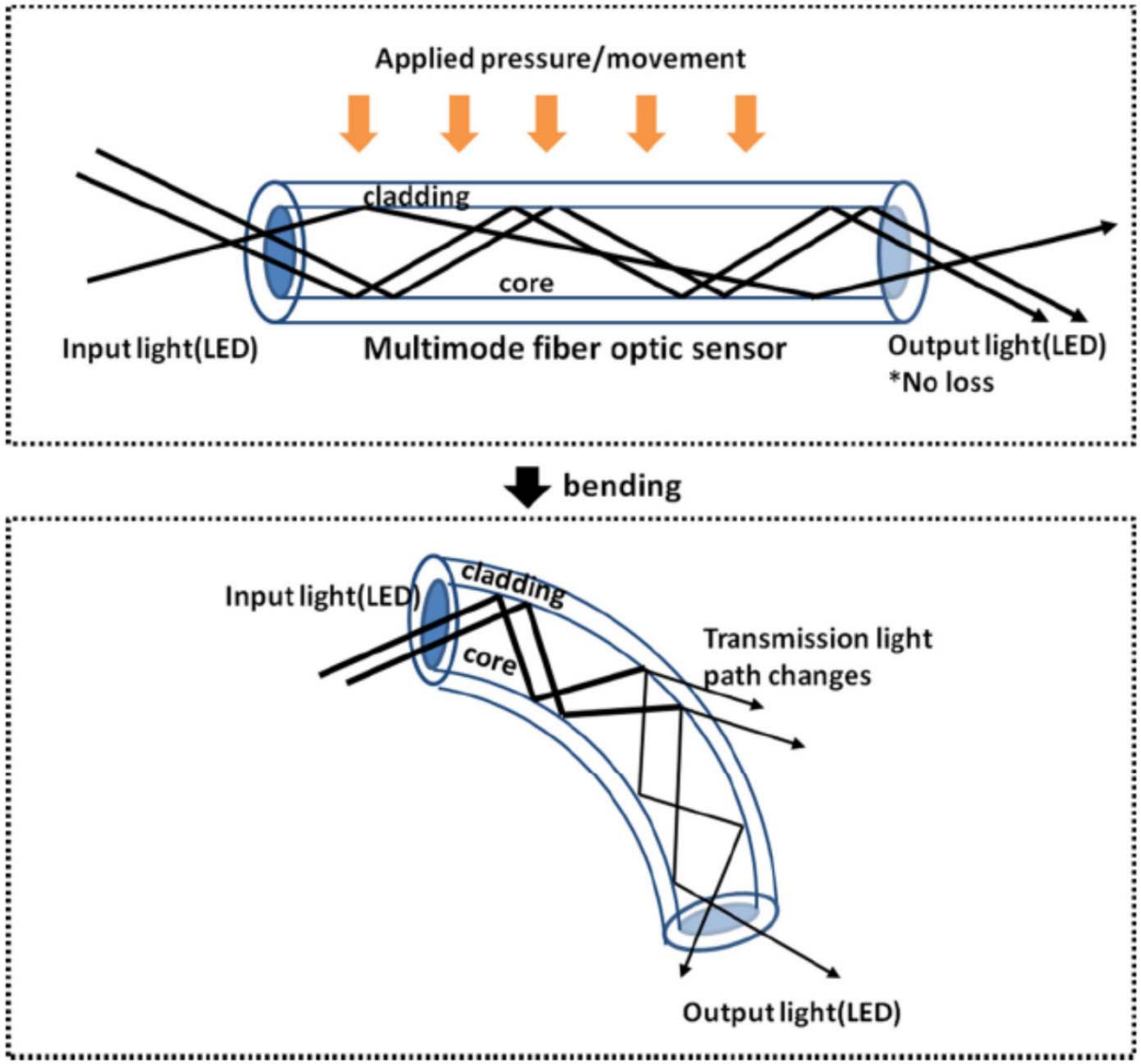
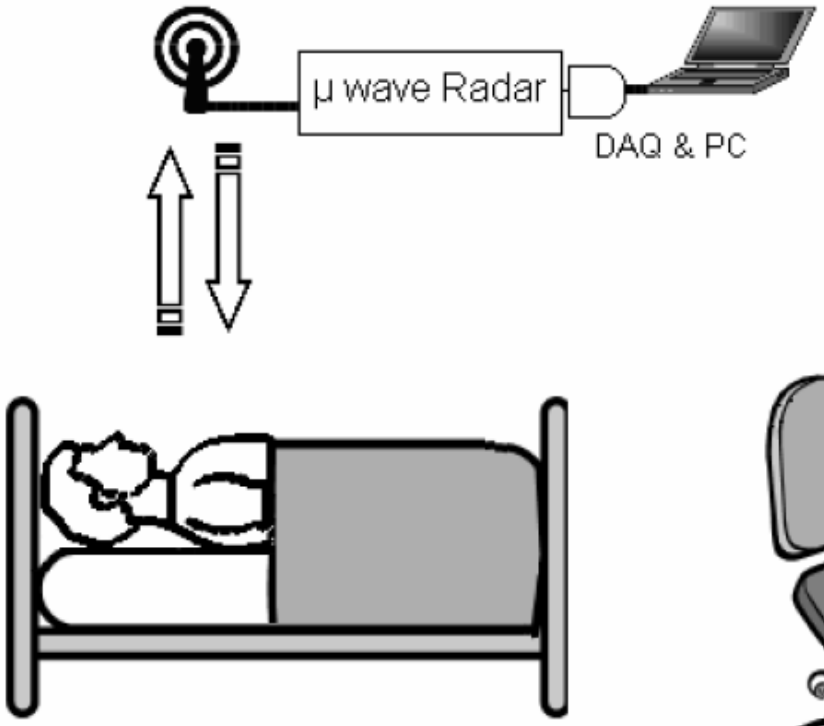


Figure 2. External applied pressure or movement bends the multimode fiber optic so that the transmission light refracts through the cladding layer, thereby causing an attenuation of optical intensity.

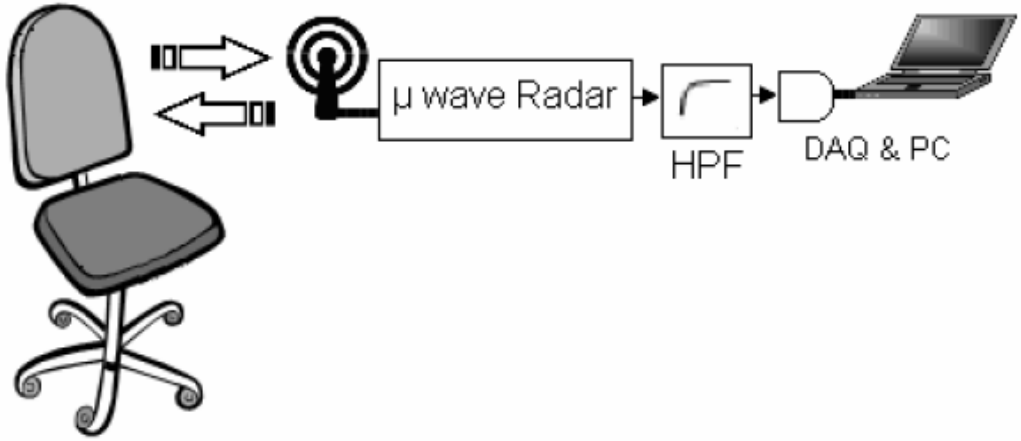
Hsu et al. Physiological Measurement 40:075005, 2019

Non-contact ballistocardiography

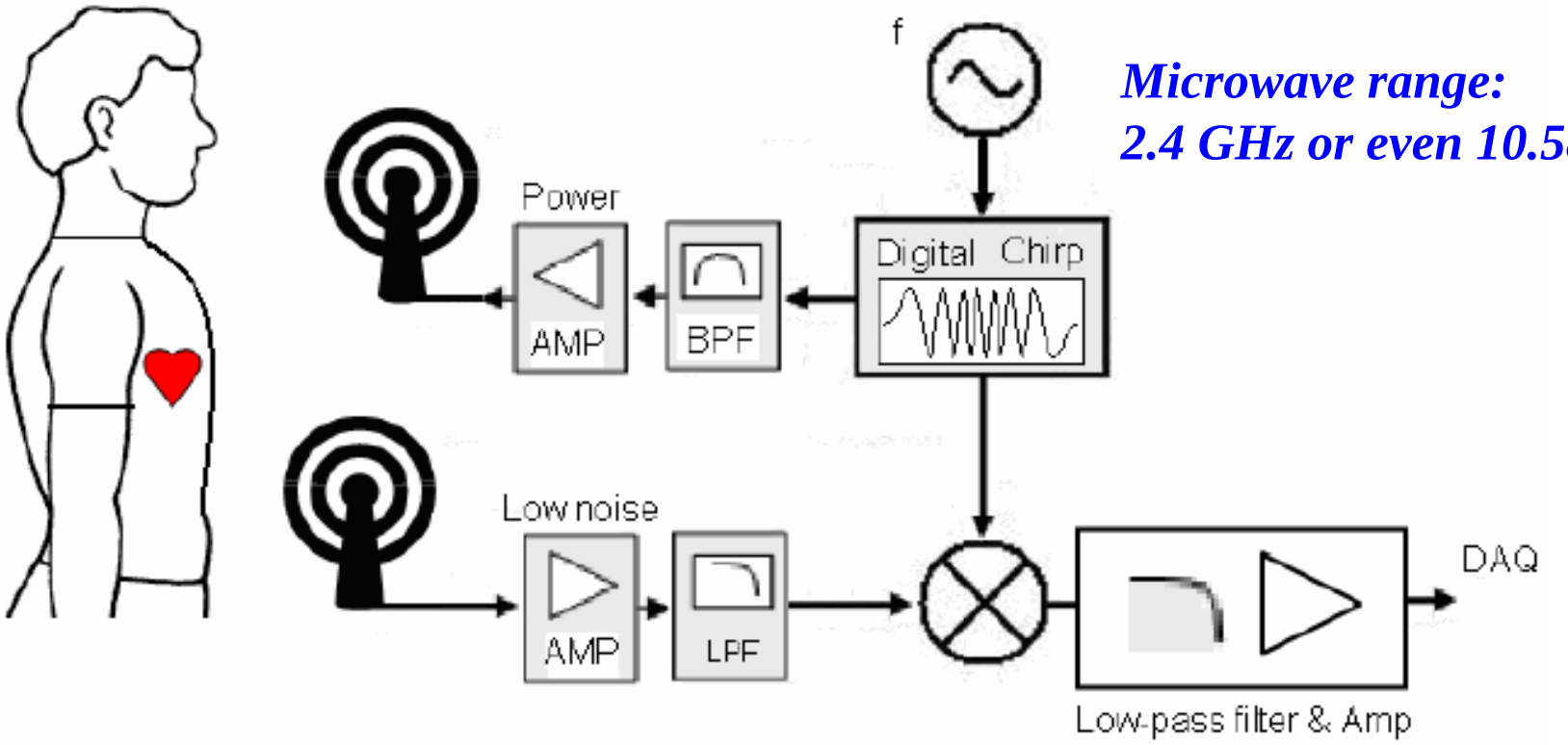
Respiratory monitoring system



Heart rate monitoring system

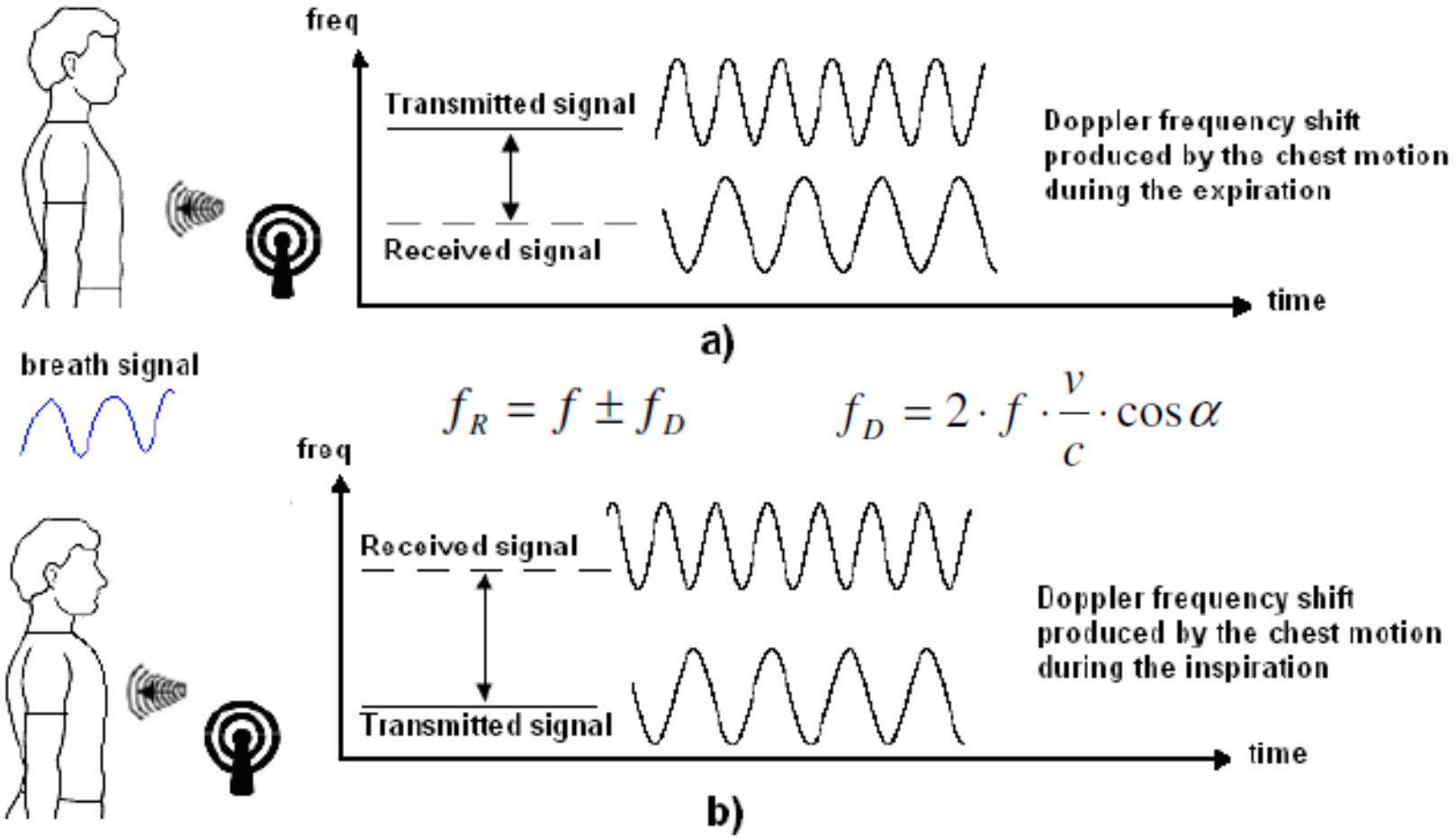


Continuous wave (CW) Doppler radar

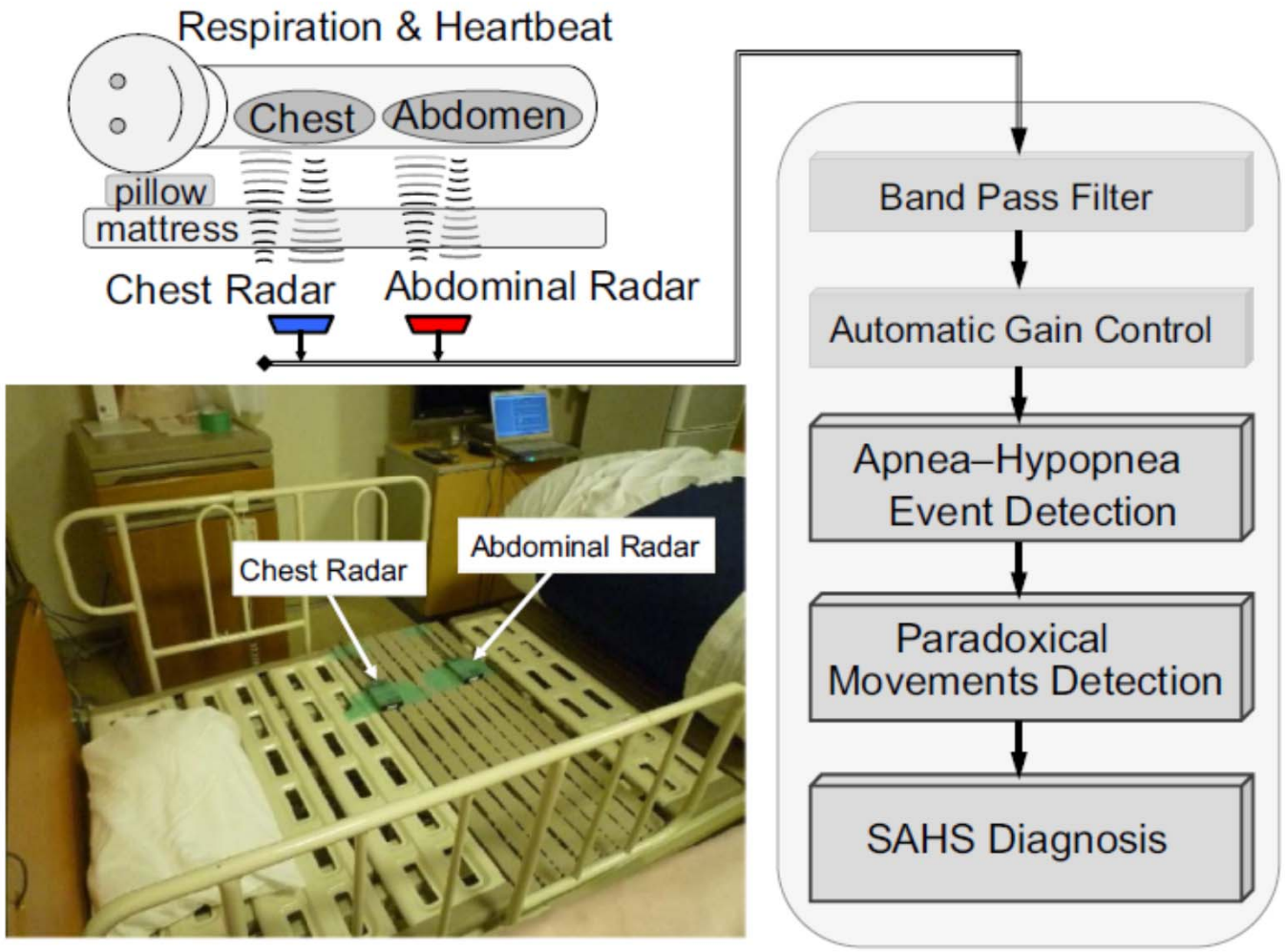


Microwave range:
2.4 GHz or even 10.587 GHz

Doppler frequency shift in received signal



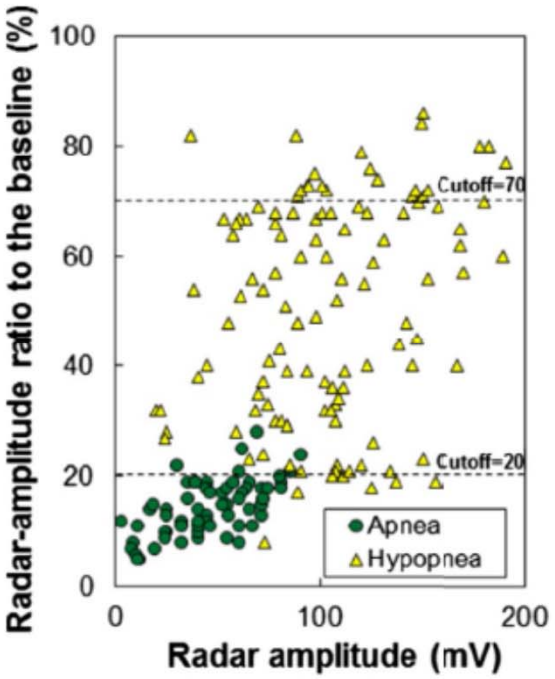
Non-contact diagnostic system for sleep apnea–hypopnea syndrome based on amplitude and phase analysis of thoracic and abdominal Doppler radars



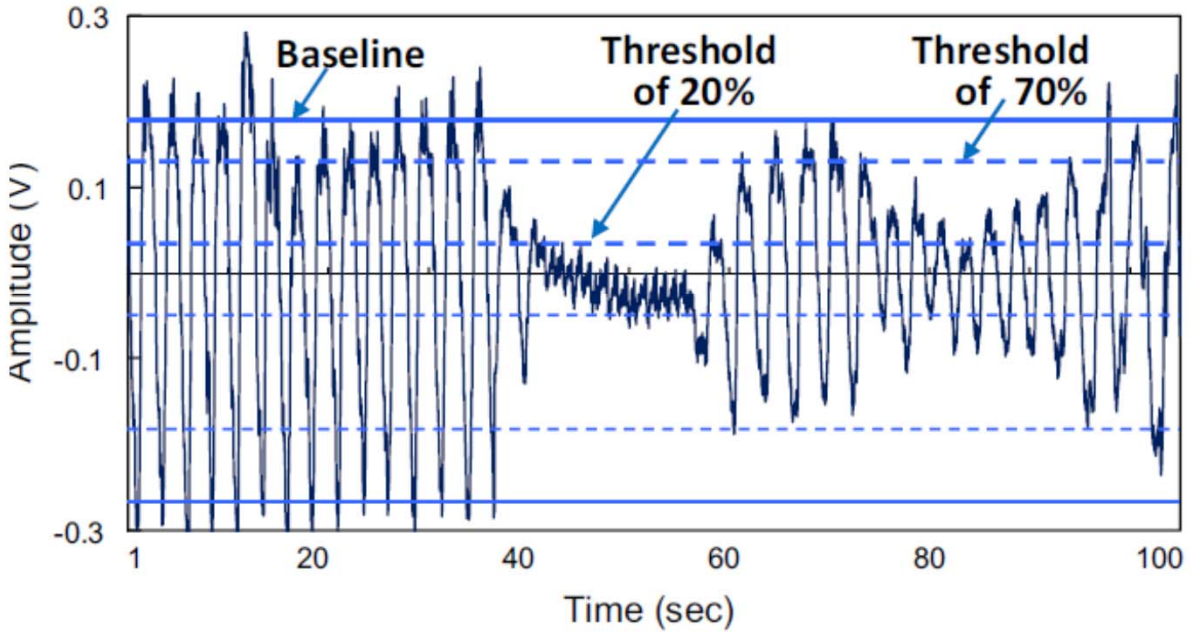
Kagawa et al, Med Biol Eng Comput (2016) 54:789–798

Apnea vs. hypopnea

The ratio of apneic events to baseline in radar amplitude



Apnea threshold, 20 %
Hypopnea threshold, 70 %



Kagawa et al, Med Biol Eng Comput (2016) 54:789–798

Reference

- O. Postolache et al. Unobtrusive and Non-invasive Sensing Solutions for On-Line Physiological Parameters Monitoring in Wearable and Autonomous Systems, Springer-Verlag Berlin Heidelberg, 2010.