Long-period grating sensors for the measurement of apexcardiogram

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Apexcardiogram (ACG)

•**ACG** – record of low-frequency vibrations of the precordium caused by heart contraction

• Related to apex (tip of the heart) movement due to heart contraction

• Mostly related to left ventricular contractions (Fig. 1.)

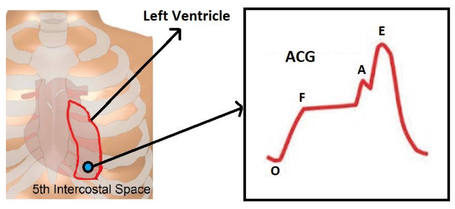


Fig. 1. Measuring position of ACG (left) and typical ACG signal for healthy subject

Significance of ACG

•Significant data in timing of systolic events of the cardiac cycle (Fig.2) [1] :

a) timing of the opening snap of the cardiac valves - the identification of the exact timing of the third (S3) and fourth heart sounds (S4) [1]

b) early diagnosis of the mitral valve stenosis or regurgitation [1].

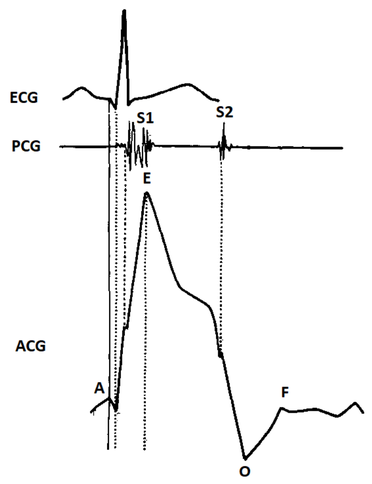


Fig. 2. Relation between ACG, PCG and ECG signal

[1] E. Tafur , L. S. Cohen , H. D. Levine, Circulation, 30(3), 381–391 (1964)

Existing ACG measuring methods

•Measuring mechanical displacements of chest wall (electro manometer sensor; piezoelectric microphone sensor ; crystal-microphone sensor (Fig. 4.)) [2].

• advantages: non-invasive methods

• disadvantages: potential noise caused by electrical interference ; technical difficulties in their application on body surface.

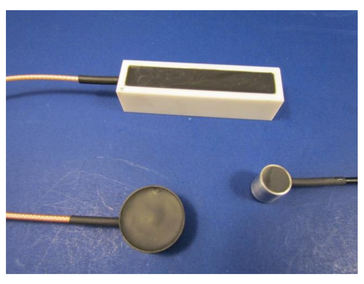


Fig. 3. Examples of electromanometer sensor (left) and piezoelectric microphone sensor (right)

[2] N. Coulshed, E. J. Epstein, Br Heart J. ,25(6) , 697–708 (1962).

Long period grating (LPG) fiber-optic sensor

- Bending-sensitive optical spectral characteristic
- Linear range output (curvature 1- 5 m^{-1})
- Suitable for measuring body surface vibrations -> vibrations of the precordium (ACG)

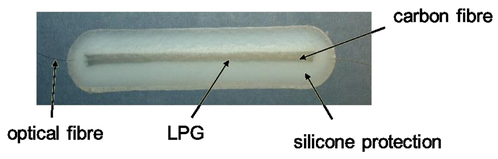


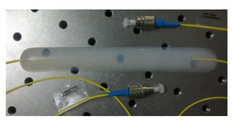
Fig. 4. LPG sensor

Measuring device

- **Electrocardiographic (ECG) sensor**

- **Phonocardiographic (PCG) sensor**

- **Long period grating (LPG) fiber-optic sensor**



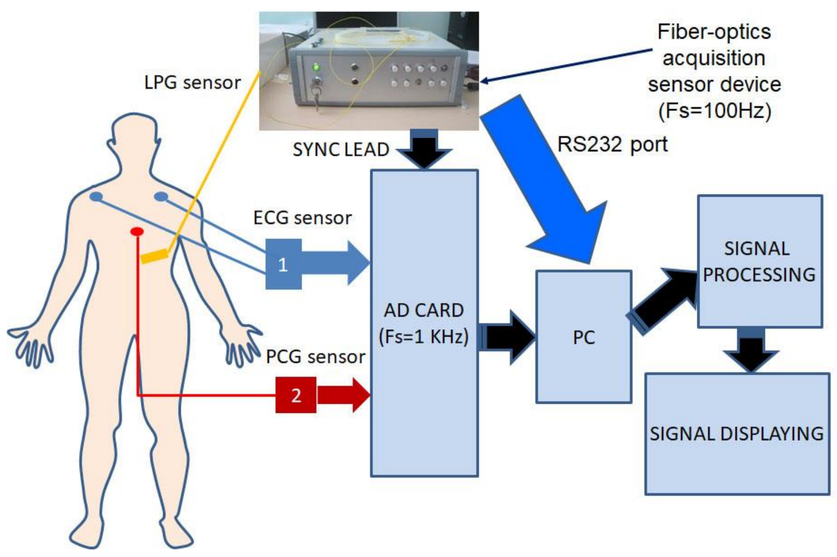


Fig. 5. Multi sensoring measuring system with LPG, ECG and PCG sensors

Measuring procedure

- 5 healthy volunteers (3 male and 2 female, 29 -51 age range)
- Three 10 second recordings signals per volunteer – supine position, without breathing
- Sensors: LPG (parasternal area of chest wall (apex area), 5th intercostal space), ECG (I lead), PCG (upper right sternal border) (Fig. 6).

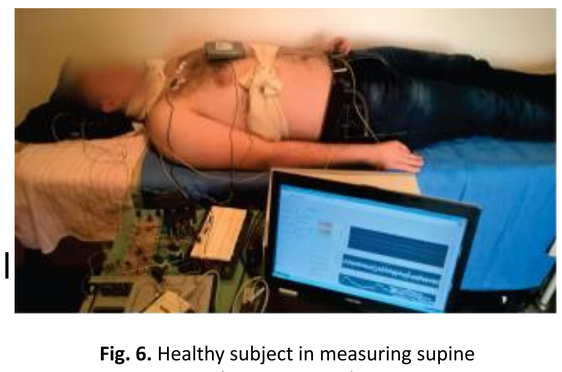


Fig. 6. Healthy subject in measuring supine position with LPG, ECG and PCG sensor

Data processing

Preprocessing algorithm:

- Time synchronization between devices
- Resampling signal (1kHz-> 100Hz)
- Low-pass filtering
- Moving average filtering
- High-pass filtering (removing baseline wandering)

Processing algorithm:

- R point detection
- Creating median beat signals

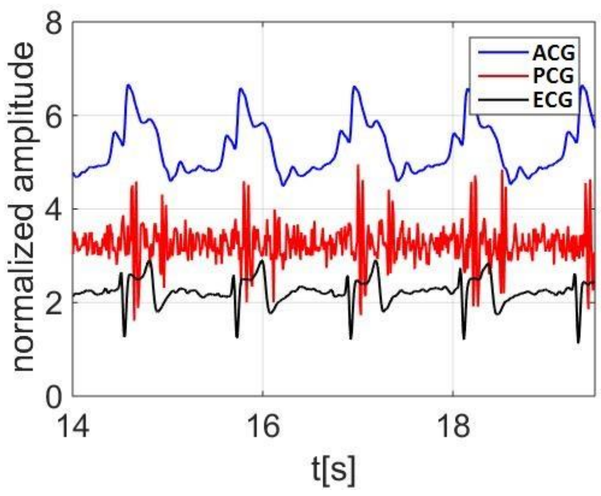


Fig. 7. ACG, PCG and ECG signals after preprocessing

Results

• Record signals with morphology of normal ACG – according to PCG (S1 and S2 sound) and ECG (P wave)

• Repeatable signal of ACG on each healthy volunteer

• Good signal-to-noise ratio

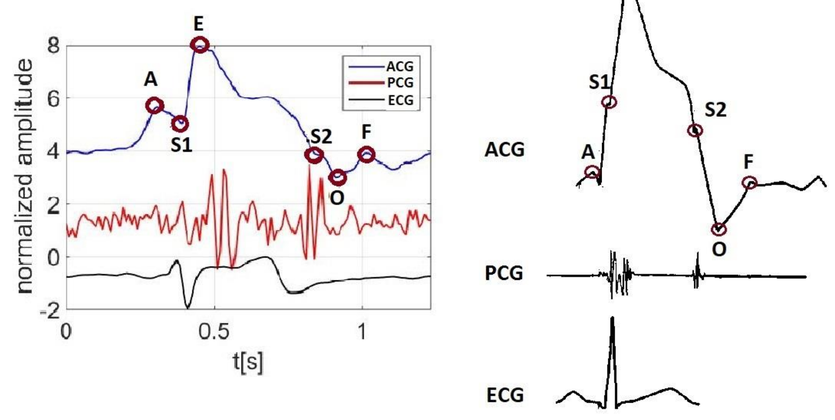


Fig. 8. Measured (Left) and standard ACG (right), with corresponding morphology time points (A, S1, E, S2, O and F), according to PCG and ECG

Conclusion

•LPG sensors are able to measure normal ACG: repeatable signals ; normal morphology; significant signal-to-noise ratio

•LPG sensor advantages: non-invasive; inexpensive ;easy to use ; do not require highly trained medical personnel

• Could be implemented in primary healthcare

Future work:

• Application of measuring method in a clinical study (10 healthy volunteers, 10 patients with heart diagnosis)