

Bed Sensor for Sleep Monitoring

Non-contacting Bed Sensor is developed for sleep analysis by VTT. It includes eight pressure sensor foils placed under mattress measuring multichannel ballistocardiographic (BCG) signals. Heart beat, respiration and activity signals are extracted on-line with DSP algorithms. Sleep analysis is calculated afterwards with automatic methods.

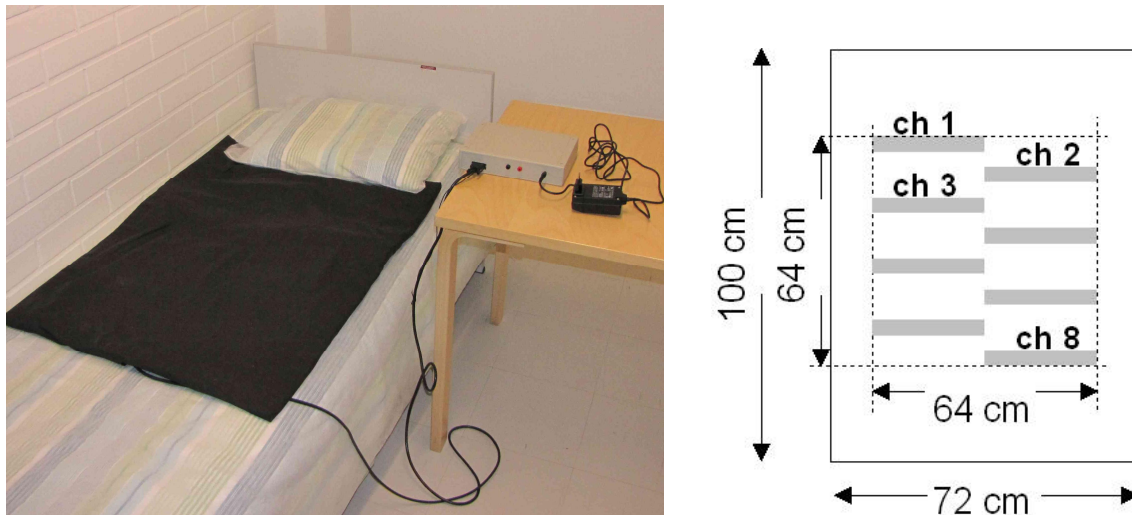


Figure 1. The unobtrusive Bed Sensor can be placed in below the bed mattress. Measured signals and the on-board processed results are stored automatically into memory card. Rightmost graph shows the sensor electrode positions over the black colored sensor mattress area.

The Bed Sensor has been compared with the standard references at the sleep laboratory of the Finnish Institute of Occupational Health (FIOH). Firstly, the periods including movement artifacts are removed, and the comparison is done with coverage of 88 % [1]:

Subjects	Total nights / hours	measurement coverage [%]	Heart beat interval error [%]	respiration cycle error [%]	sleep posture classification succeed [%]
6	15 / 100	88	0,35	1,5	92

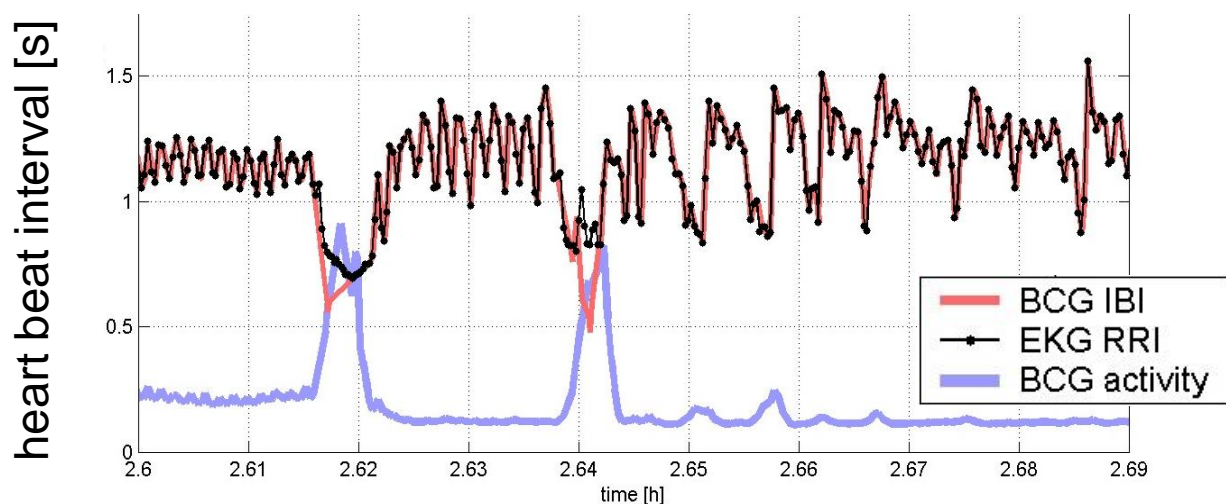


Figure 2. Bed Sensor heart beat interval (BCG IBI) against EKG R-R interval during six minutes. Heart beat is measured with good accuracy when the movement activity is low.

Respiration induced Heart Rate Variability (HRV) during sleep

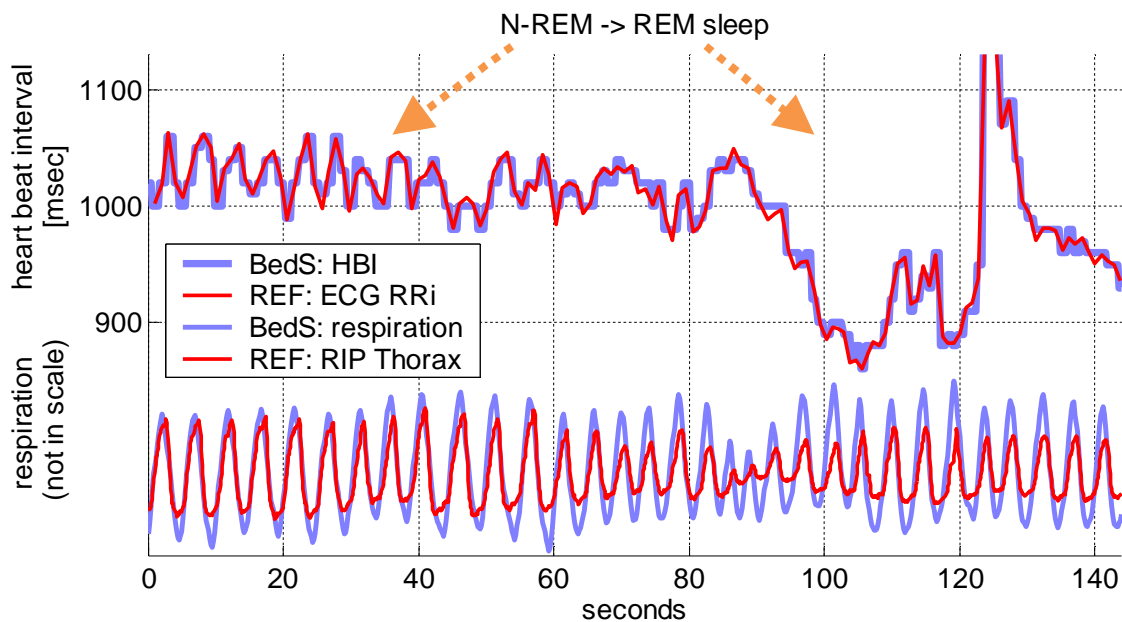


Figure 3. BedSensor heart rate and respiration are shown with blue color and references with red color. Respiration induced fast HF-HRV is at strongest during N-REM sleep, while during REM sleep the HF-HRV decreases and low frequency LF- HRV increases.

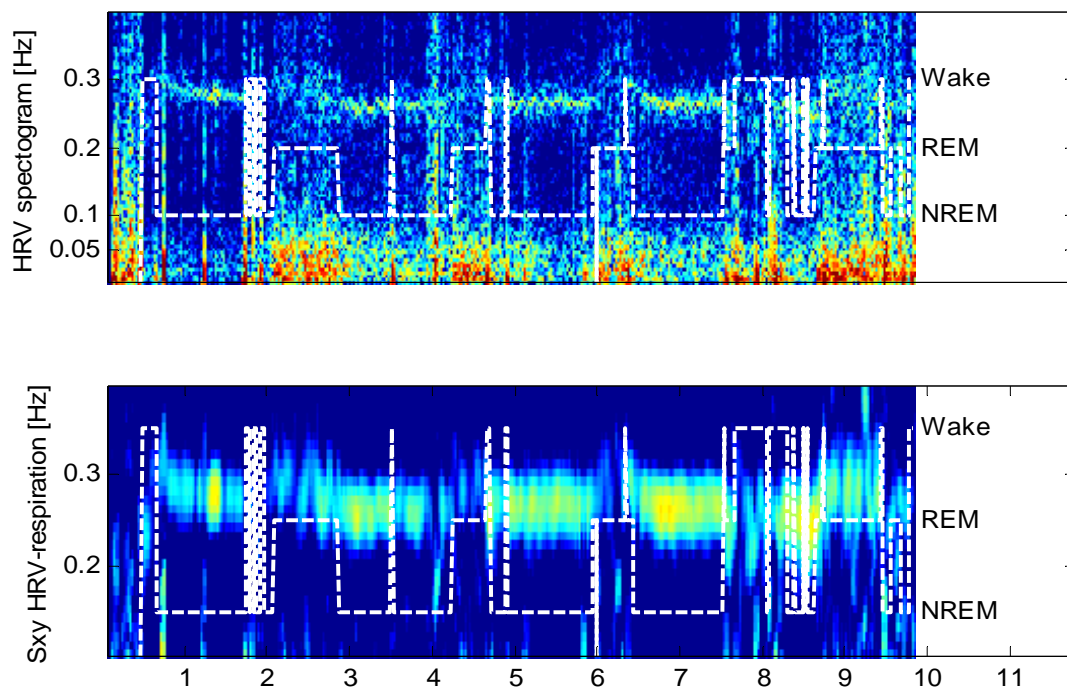


Figure 4. HRV spectrogram analysis for a ten hours long sleep recording. Vertical axis shows HRV frequency, and HRV-HF component is in the range between 0.15 Hz – 0.4 Hz. The sleep scoring results are shown with the white dashed line. The HRV-HF component is strong during the NREM sleep, and the HRV-LF component is strong during the REM sleep and wake stage.

The lower graph shows the cross-spectrogram between the HRV and the respiration, to emphasize the respiration related HRV-HF component.

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- [1] **Kortelainen J., Virkkala J.:** FFT averaging of multichannel BCG signals from bed mattress sensor to improve estimation of heart beat interval, 29th IEEE EMBC, August 23-26, 2007, Lyon, France.
- [2] **Kortelainen Juha M., Mendez M.O., Bianchi A.M., Matteucci M., Cerutti, S.:** Sleep staging based on signals acquired through bed sensor. IEEE TITB, Vol. 14 (2010) No: 3, 776-785