



HealthGear: A Real-time Wearable System for Monitoring and Detecting Sleep Apnea

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Introduction

- **Need for wearable health monitoring devices:**
 - Aging population in developed countries
 - Rural areas in developing countries
- **They would:**
 - Enable the detection of early signs of health deterioration
 - Notify health care providers in critical situations
 - Enhance sense of connectedness with loved ones
 - Find correlations between lifestyle and health
 - New dimension in sports conditioning
 - Transform health care

However...

- **To make these devices practical a series of technical, legal and sociological obstacles need to be overcome:**
 - **Non-intrusive**
 - **Comfortable to wear**
 - **Efficient in power consumption**
 - **Preserve privacy**
 - **User-friendly**
 - **Low failure rate**
 - **Minimal false alarms**

HealthGear

- **Real-time, wearable health monitoring system**
- **Cell phone as central processing unit (Audiovox SMT5600)**
 - **Personal Computer for millions of people**
 - **Communication capabilities (GPRS, etc)**
 - **Multimodal: camera, microphone, etc**
- **Continuous recording of blood oximetry, heart-rate and plethysmographic signal**
- **Real-time analysis and presentation of physiological data to the user**

HealthGear

Bluetooth Module

Your text here

Cell Phone

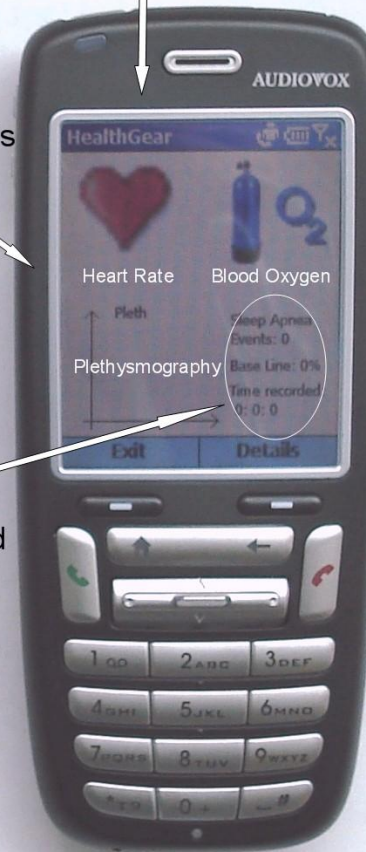
DSP Unit

HealthGear's
Interface

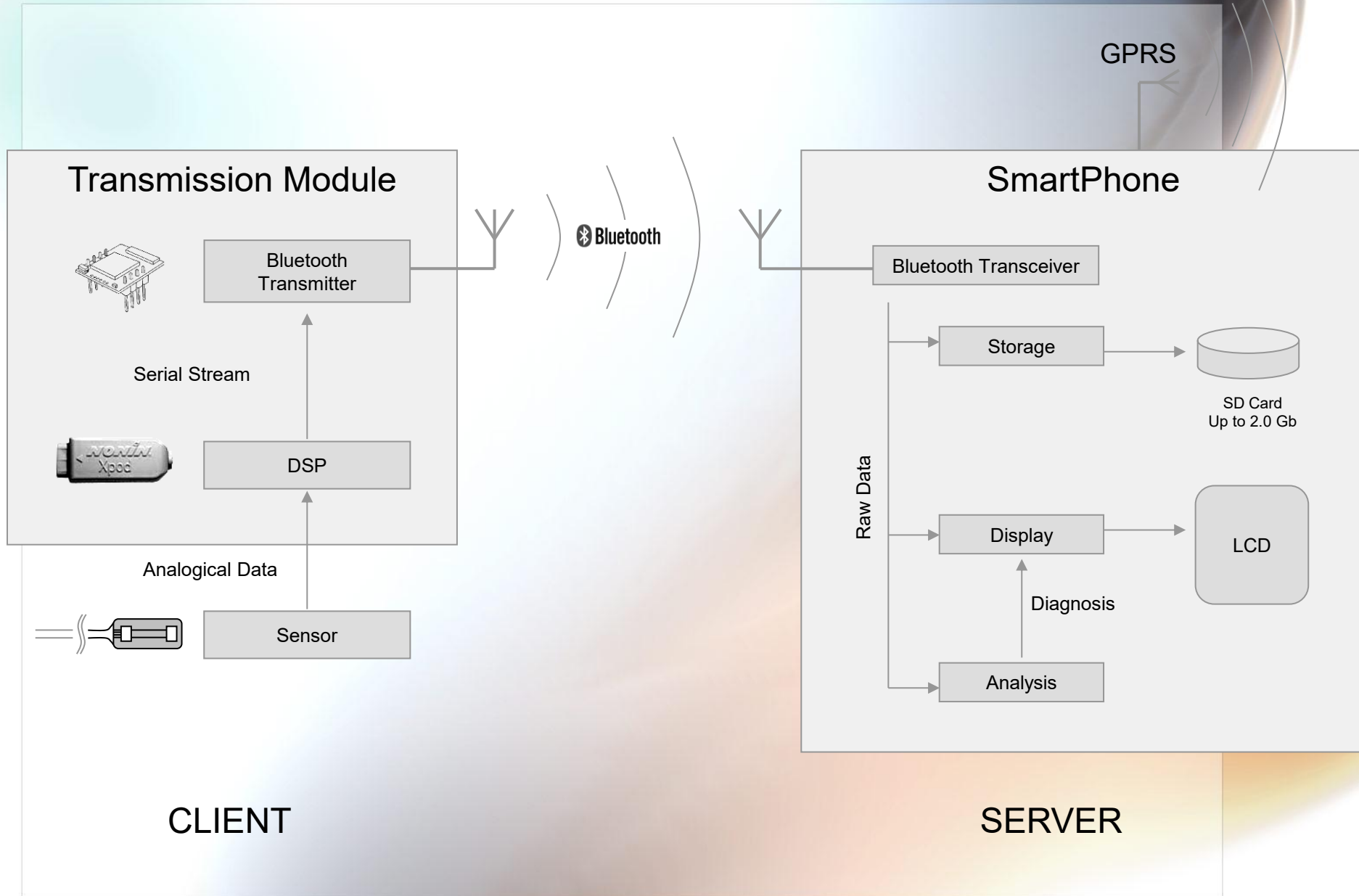
Oximeter

Batteries

Automatic
Sleep Apnea
Detection and
Analysis



Architecture



Sleep Apnea

- **Underdiagnosed but common condition**
 - Affects children and adults
 - 4% in men and 2% in women (higher for elderly)
 - Untreated causes \$3.4 billion of medical costs
 - 40 million undiagnosed Americans
- **Periods of interrupted breathing (apnea) and periods of reduced breathing (hypoapnea)**
- **Leads to:**
 - Hypoxia, asphyxia and awakenings
 - Increased heart-rate, high blood pressure
 - Extreme fatigue, poor concentration
 - Compromised immune system
 - Cardio/cerebrovascular problems

Sleep Apnea: Diagnosis

- **Nocturnal Polysomnography (PSG):**
 - In sleep center for 1-2 nights
 - Continuous, simultaneous multi-channel measurements of 8 physiological signals 😊
 - Very expensive, cumbersome, time consuming, just one sample and subject to manual scoring and human error ☹️
- **Pulse oximetry:**
 - Useful as screening and diagnostic tool
 - One simple, light-weight sensor on finger, toe or earlobe

Automatic Detection of Sleep Apnea

- **Multithreshold Time Analysis:**
 - Defines multiple levels of desaturation (drop gap) and resaturation (return gap)
 - Desaturation starts as soon as the oxygen level falls below a baseline by a certain amount and continues until the signal recovers to a level, which is lower than the baseline by 25% of the specified amount
 - Our algorithm defines 11 threshold for all possible values of desaturation from 5% to 15% in increments of 1%

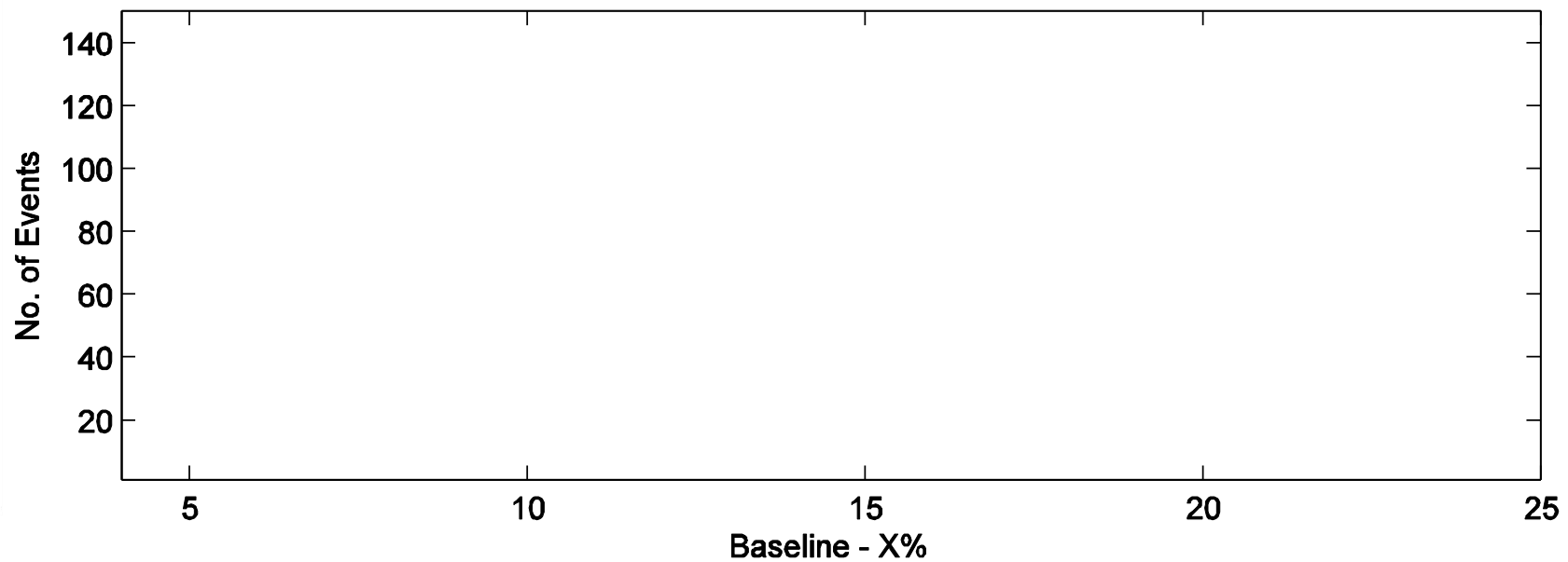
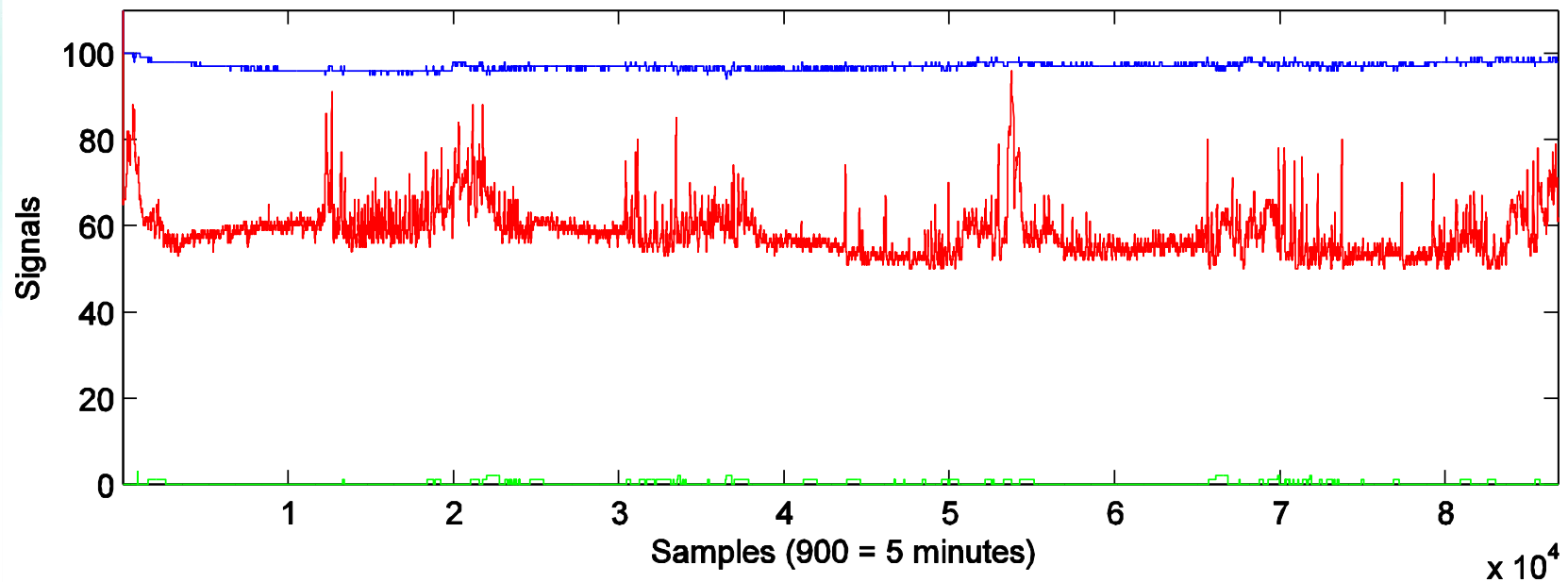
Automatic Detection of Sleep Apnea

- **Spectral Analysis:**
 - **Periodogram of the mean-subtracted oximetry signal**
 - **Sleep apnea events are detected as a peak in the range 0.015-0.04Hz**
 - **This frequency has a fisiological explanation corresponding to the typical lenghts of apnea events**

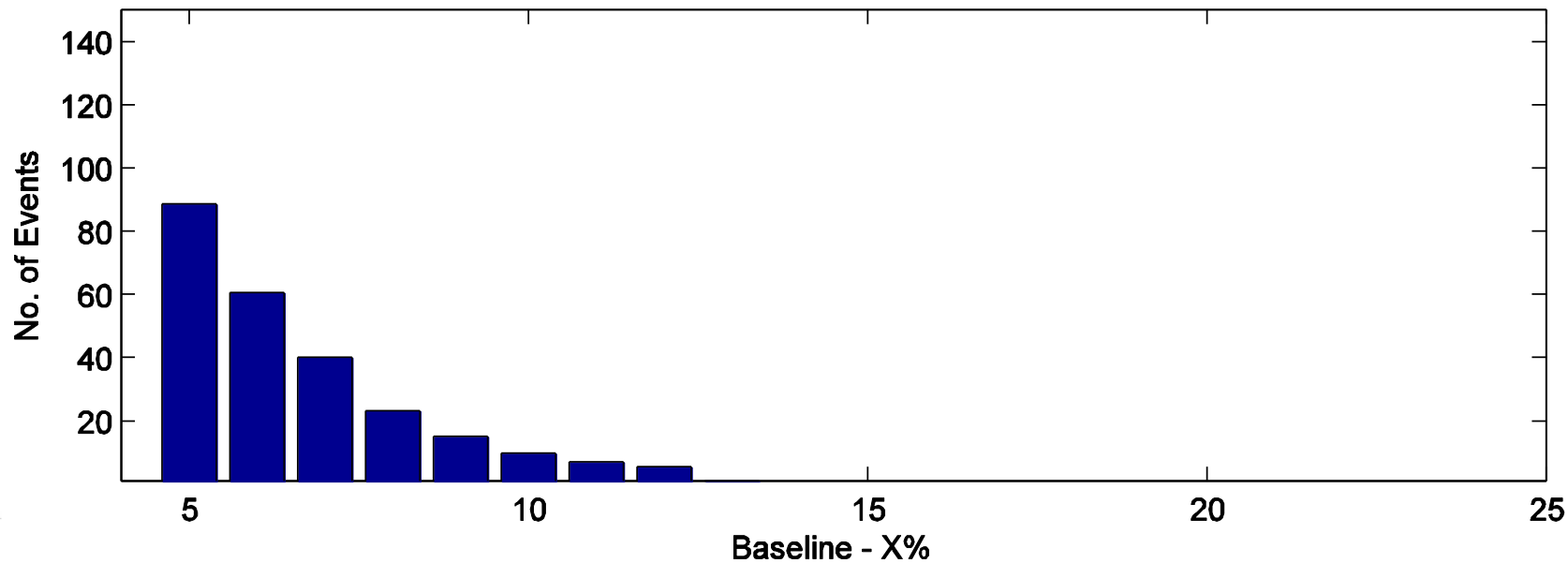
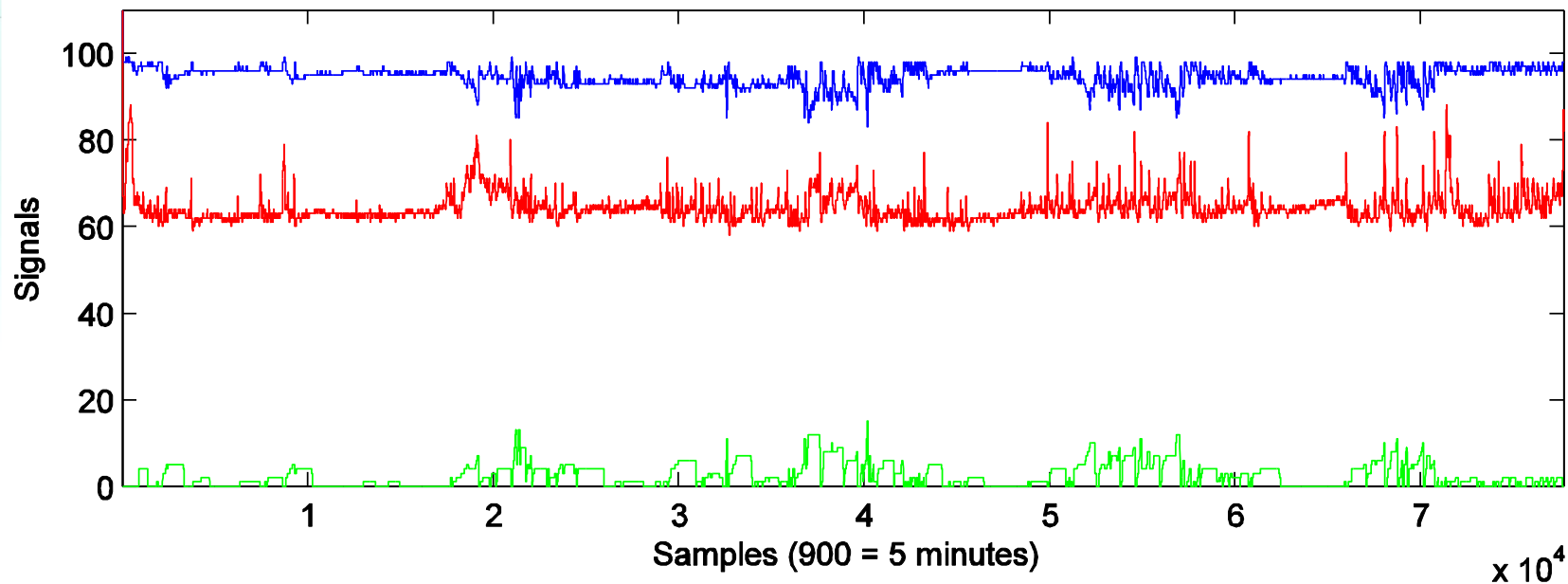
Sleep Study

- **21 volunteers:**
 - 80% male, ages 25-65
 - 30% healthy, 70% with sleep apnea or suspected
- **Wore HealthGear for one full night in their own homes**

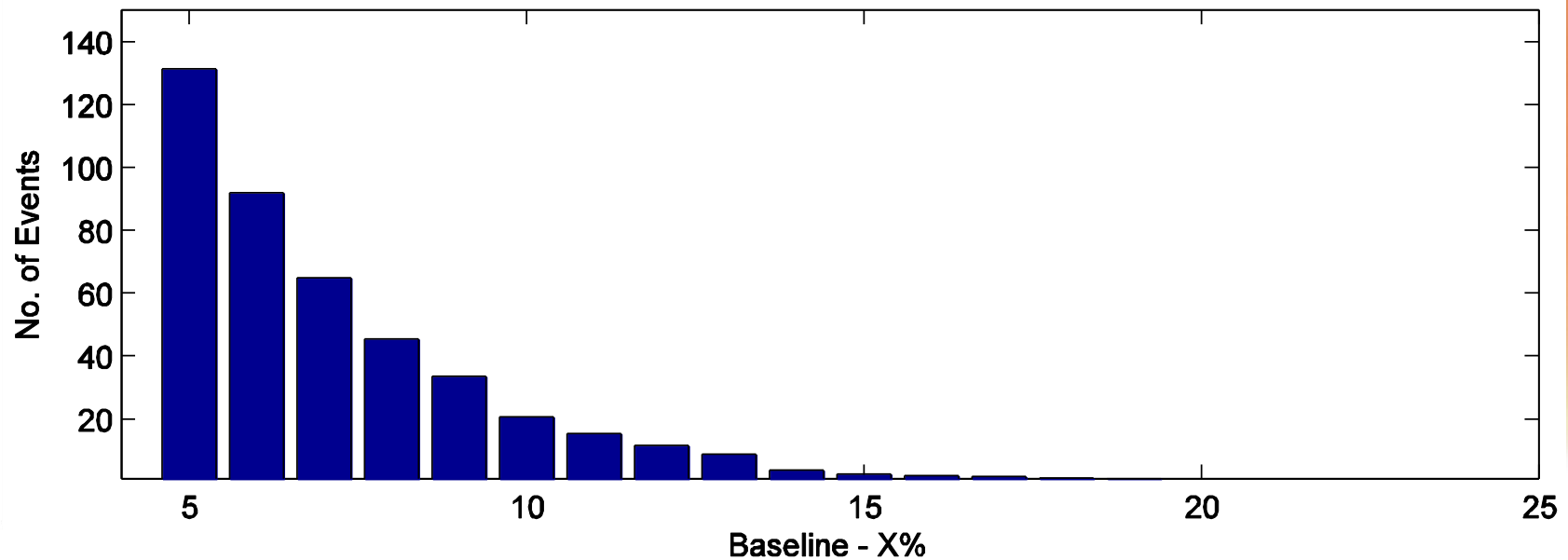
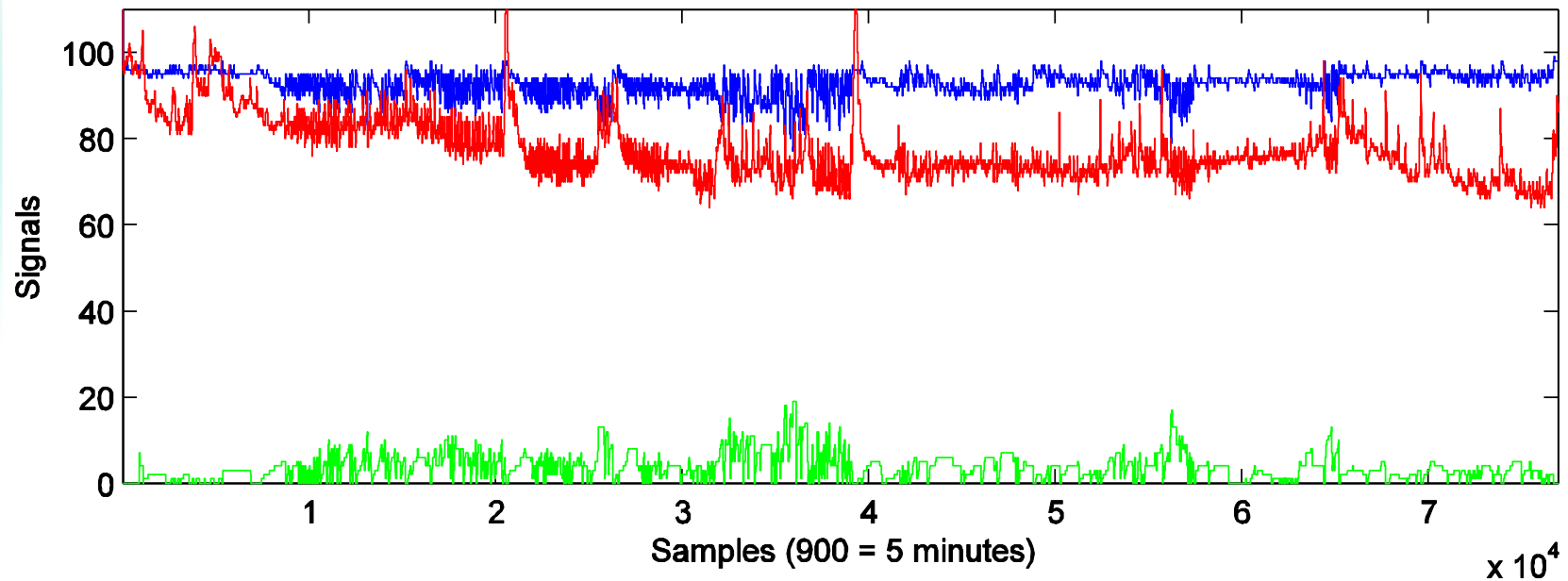
No Apnea



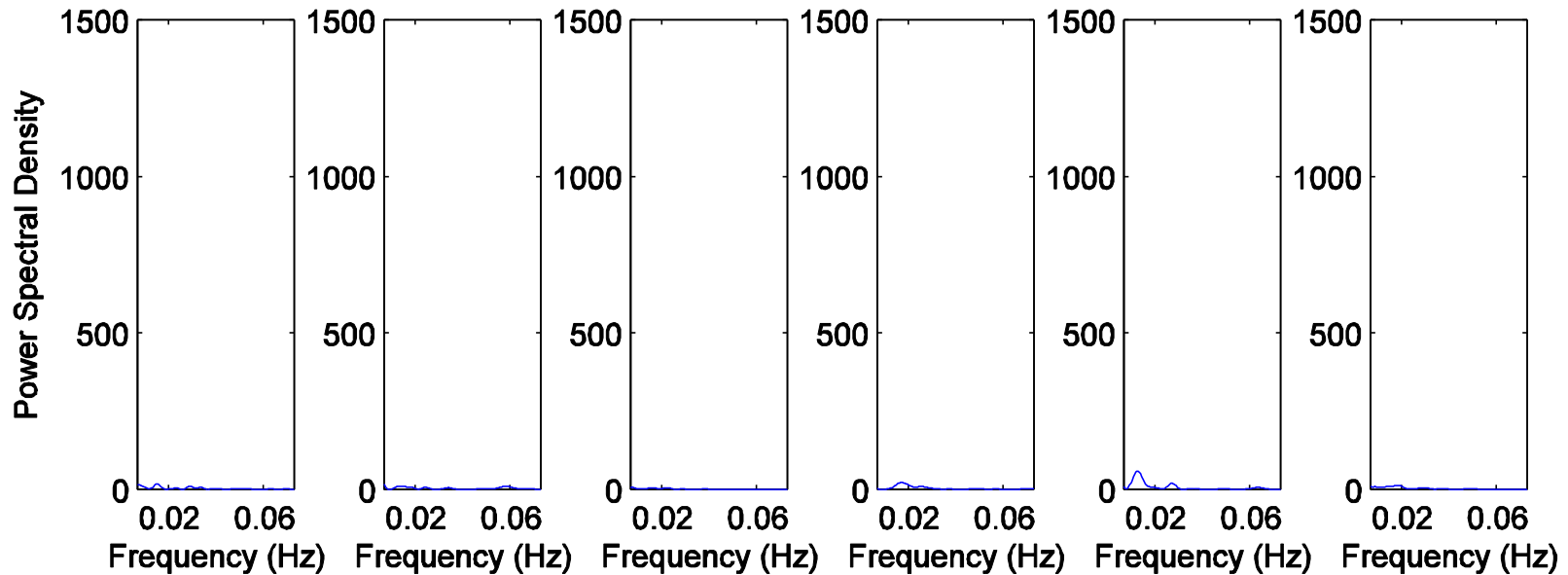
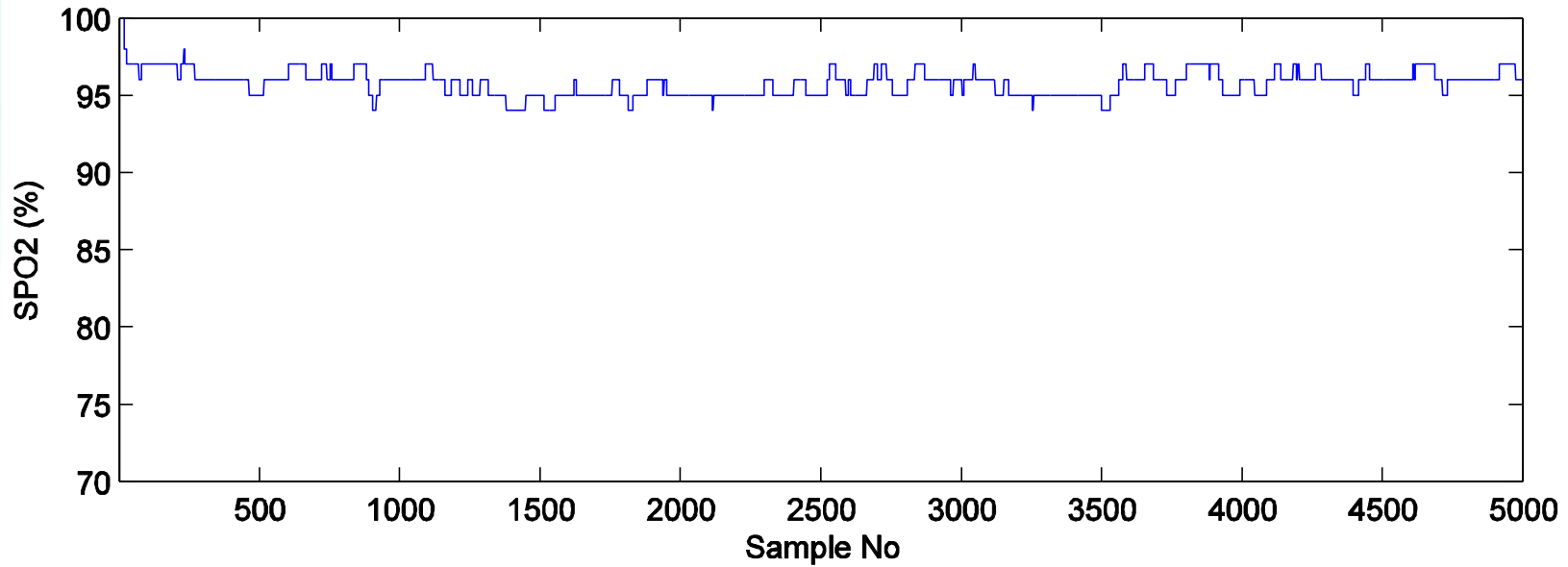
Mild-Severe Apnea



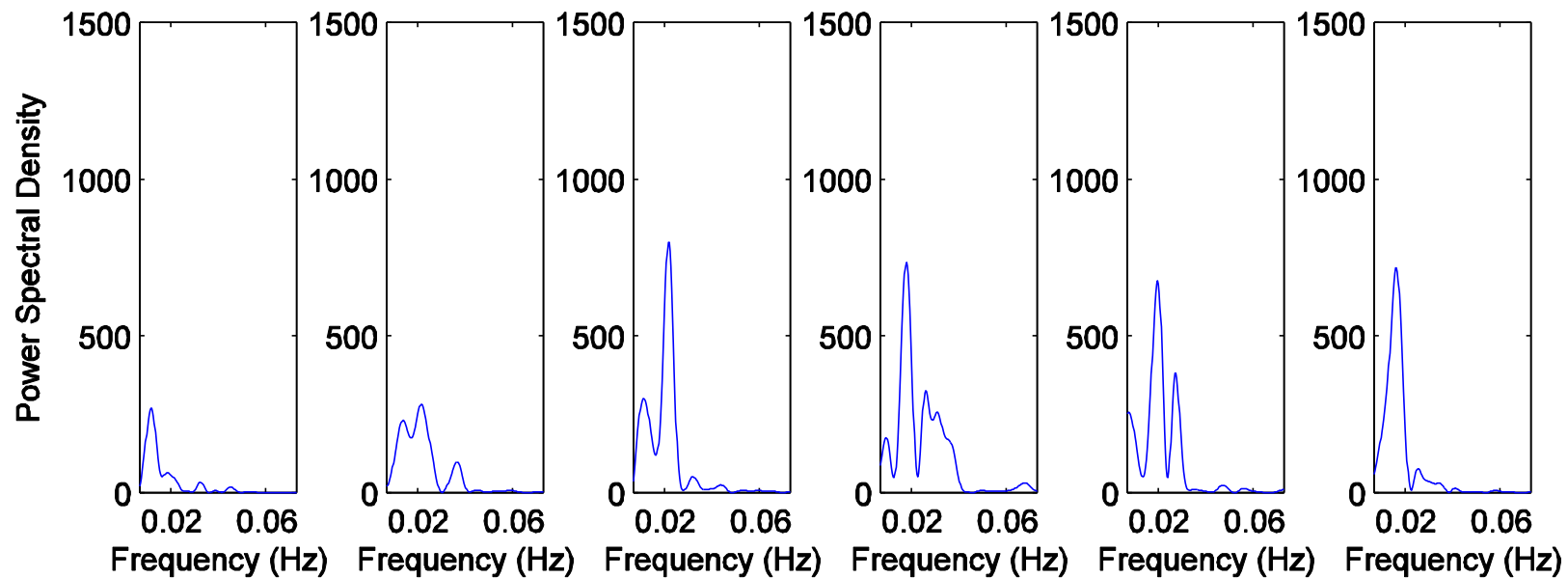
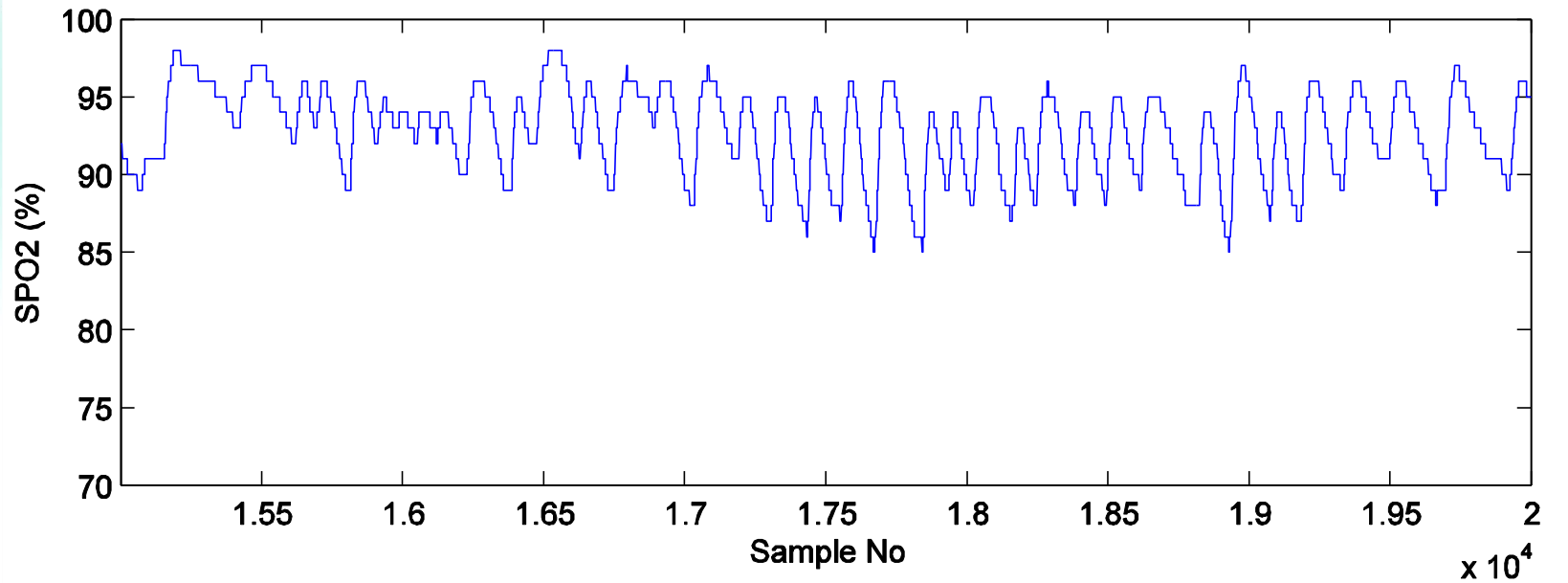
Severe Apnea



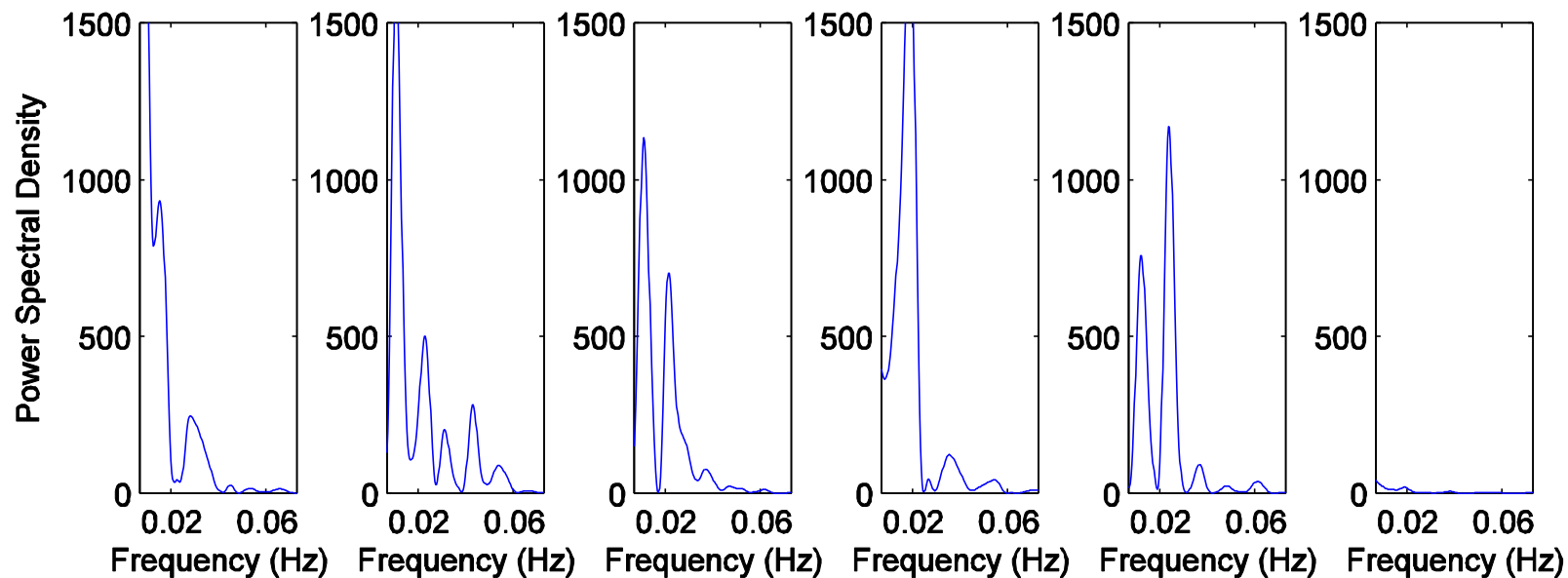
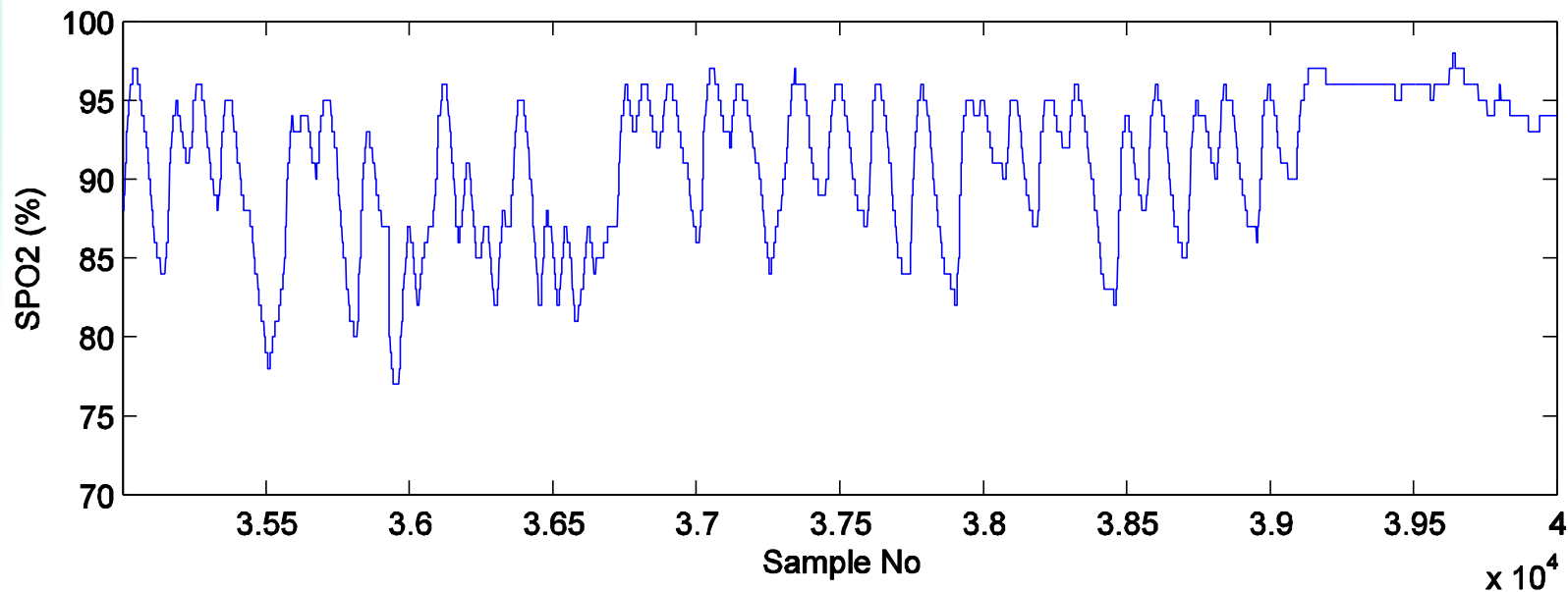
No Apnea



Mild-Severe Apnea



Severe Apnea



Conclusions & Future Work

- **Accurate sleep apnea detection**
- **Light-weight sleep monitoring system**
- **High acceptance rates**

- **Long-term sleep studies**
- **Collaboration with doctors**
- **Additional sensors**
- **Identifying correlations between lifestyle, environmental factors and physiology**

Thank You!