ELECTROMYOGRAM (EMG) AND PREDICTING PRE-TERM DELIVERY

- Introduction
- Signal processing point of view
- Recording the electromyogram from the uterus
- Term Pre-term EHG DataBase (TPEHG DB)
- Preprocessing
- Behavior of signal power spectrum during pregnancy
- Signal power spectra of term and pre-term delivery records
- Hypotheses
- Characteristics of signals of term and pre-term delivery records
- Biological systems
- Hypotheses
- Non-linear signal processing techniques
- (Term Pre-term EHG DataBase (TPEHG DB))
- (Linear and non-linear signal processing techniques)

Introduction

- Premature labor (pregnancy duration < 37 weeks) is the leading cause of morbidity and also mortality in infants
- Premature labor prediction using risk factors such as diabetes, hypertension, abnormalities of the uterus, short cervix, conization, a positive fibronectin test, smoking, …, is far from certain
- Automatic, non-invasive, analysis of electromyogram (EMG) from uterus ElectroHysteroGram (EHG) can help to predict premature labor
- Successful prediction of premature labor would confirm the use of oxytocin antagonist sooner in the process of pre-term delivery

Signal processing point of view

- Using the EHG it is possible to automatically detect uterine electrical activity during both gestation and active labor
- Linear signal processing techniques which rely on the changes in the frequency power spectrum of the uterine activity are able to detect changes in individual uterine contractions as the time of delivery approaches
- Non-linear signal processing techniques (*median frequency of the signal power spectrum and sample entropy*) are able to differentiate between groups of EHG records from pregnancies where the *deliveries* were:

  1. term;

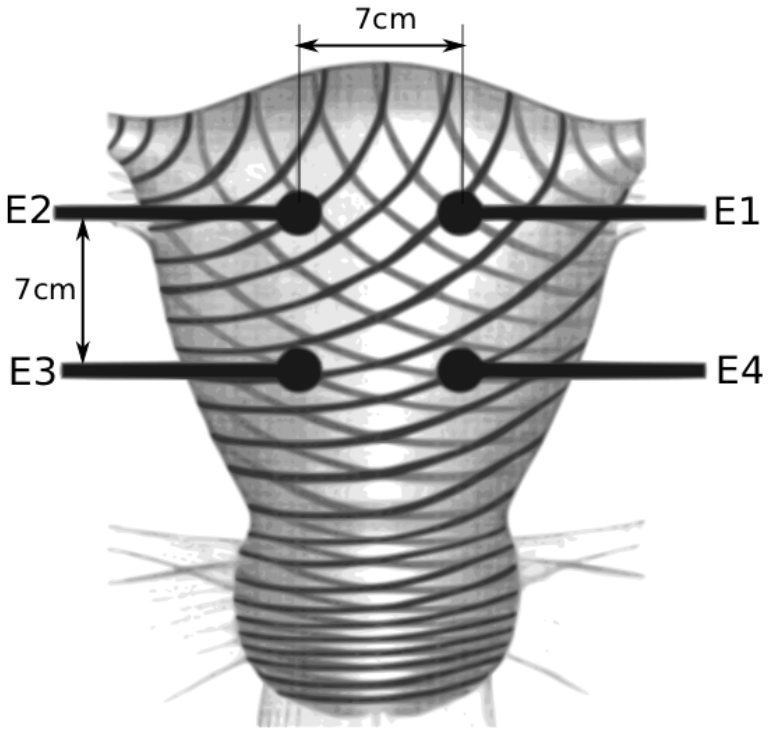
     and from pregnancies which ended,

  2. premature.

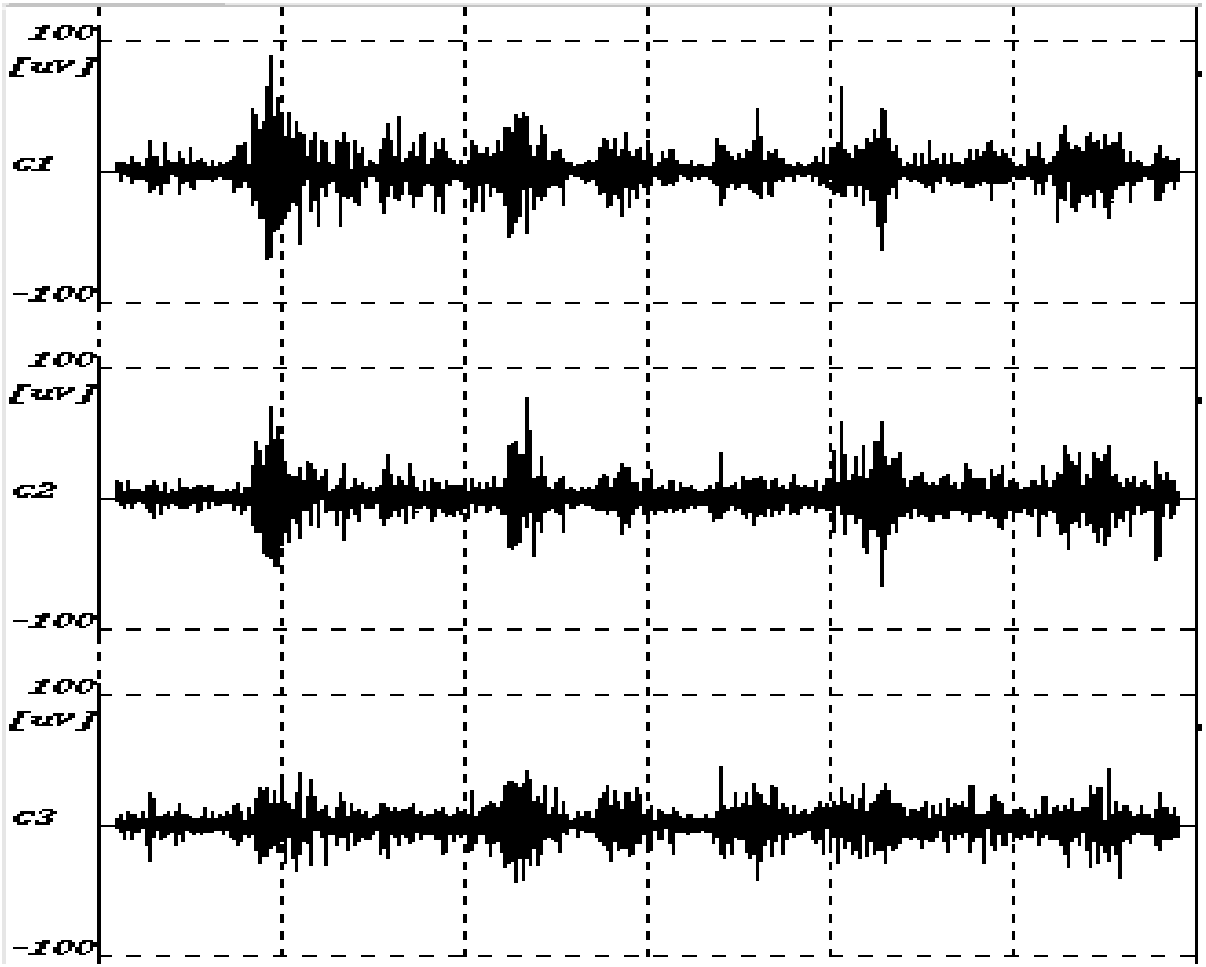
Recording the electromyogram from the uterus

- Uterine ElectroMyoGram (EMG) is termed as ElectroHysteroGram (EHG)
- The placement of the electrodes on the abdomen, above the uterine surface

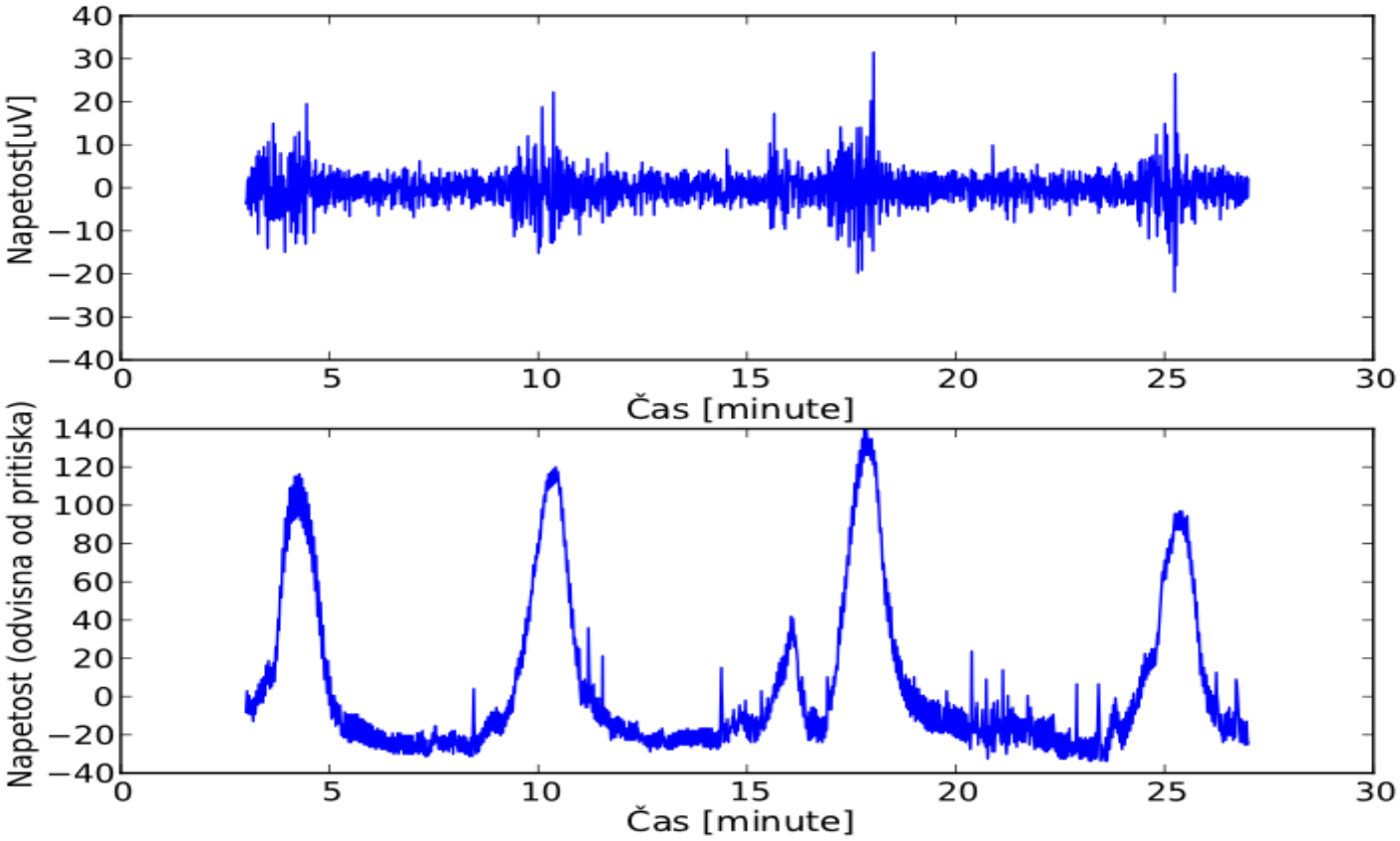
Signal 1: E2–E1,
Signal 2: E2–E3,
Signal 3: E4–E3



Recording the electromyogram from the uterus



Recording the electromyogram from the uterus

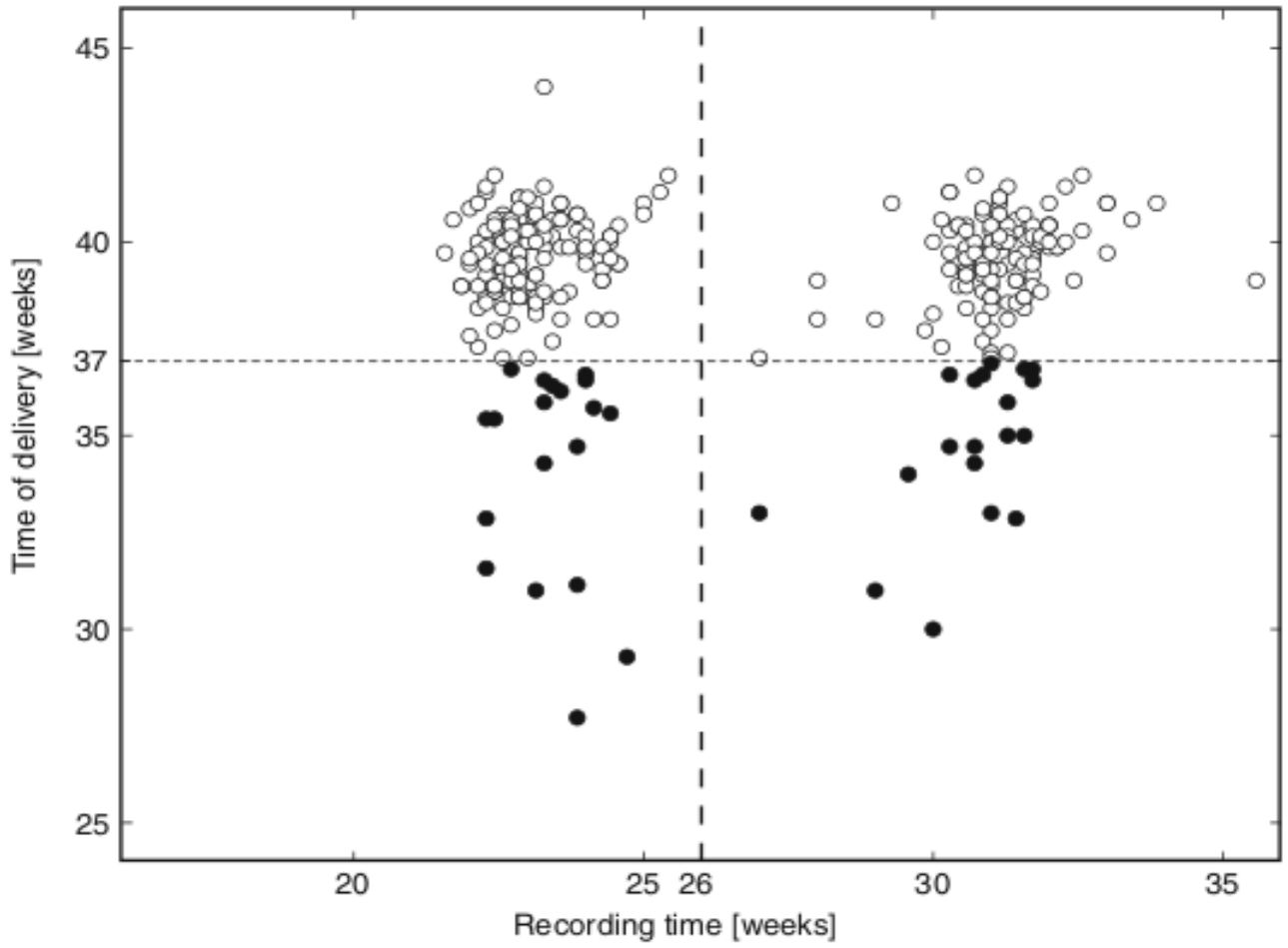


- External tocography using tocodynamometer yields relative intensity of uterine contractions and changes in basal presure (measured at fundus)

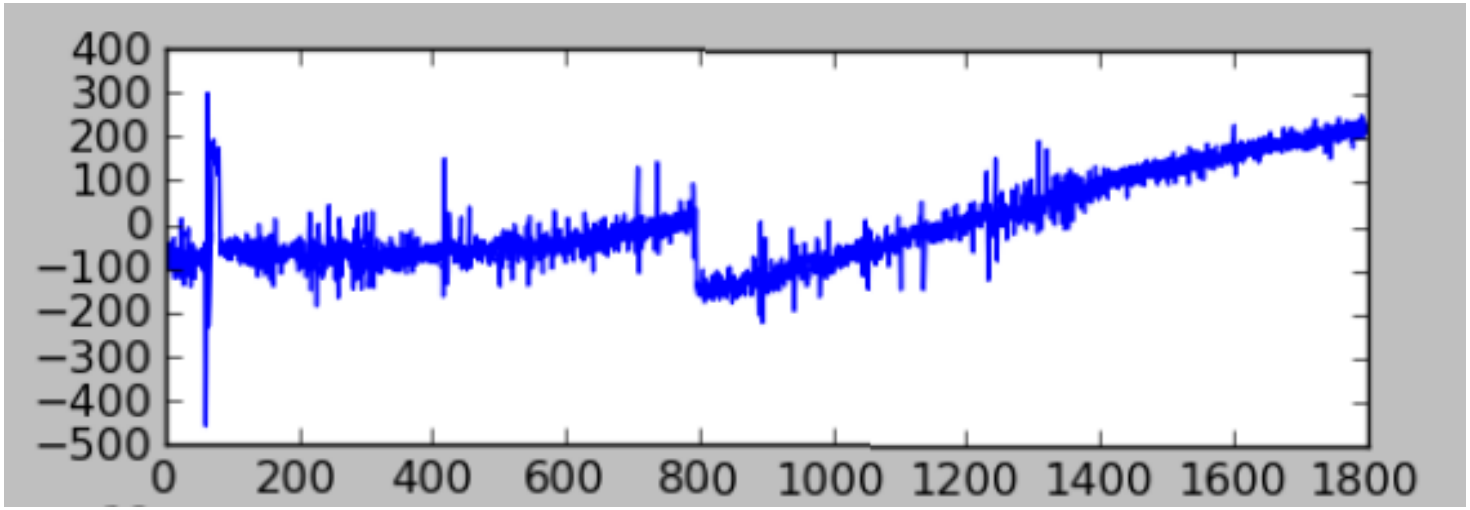
Term Pre-term EHG DataBase (TPEHG DB)

- Three hundred 30-minute ElectroHysteroGram (EHG) records
  1. 262 records from pregnancies where the deliveries were term (pregnancy duration >= 37 weeks) of which:
     a) 143 records were recorded early, before the 26th week of gestation;
     b) 119 records were recorded later, during or after the 26th week of gestation.
  2. 38 records from pregnancies which ended prematurely (pregnancy duration < 37 weeks) of which:
     a) 19 records were recorded early, before the 26th week of gestation;
     b) 19 records were recorded later, during or after the 26th week of gestation.

Term Pre-term EHG DataBase (TPEHG DB)



Preprocessing



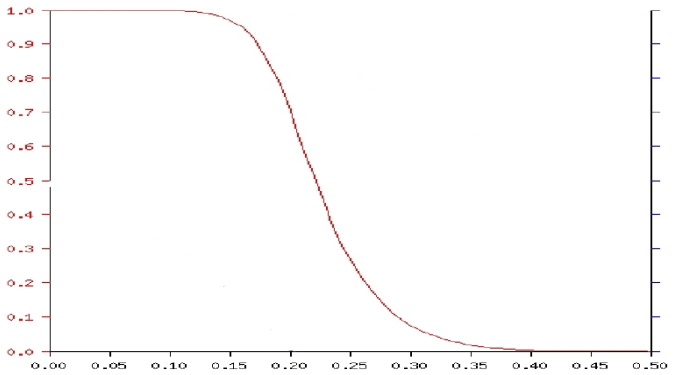
Preprocessing

- Digital Butterworth filters have a smooth frequency response and are computationally non-intensive

- Low-pass $$\left|H_L(\Omega)\right|^2 = \frac{1}{1+\left(\frac{\Omega}{\Omega_C}\right)^{2N}}$$

- High-pass $$\left|H_H(\Omega)\right|^2 = \frac{1}{1+\left(\frac{\Omega_C}{\Omega}\right)^{2N}}$$

$\left|H_L(\Omega)\right|$



- Their major drawback, the phase-shifting, is especially troublesome when using high-pass filtering
- The phase-shift can be eliminated by filtering the whole signal twice in different directions, forward and then again backward, thus obtaining a well filtered signal with zero phase shift

Preprocessing

- Forward-backward (double pass) filtering (zero phase shift, squared transfer characteristic)

$$z_1[n] = h[n] * x[n],$$
$$z_2[n] = h[n] * z_1[-n],$$
$$s[n] = z_2[-n]$$

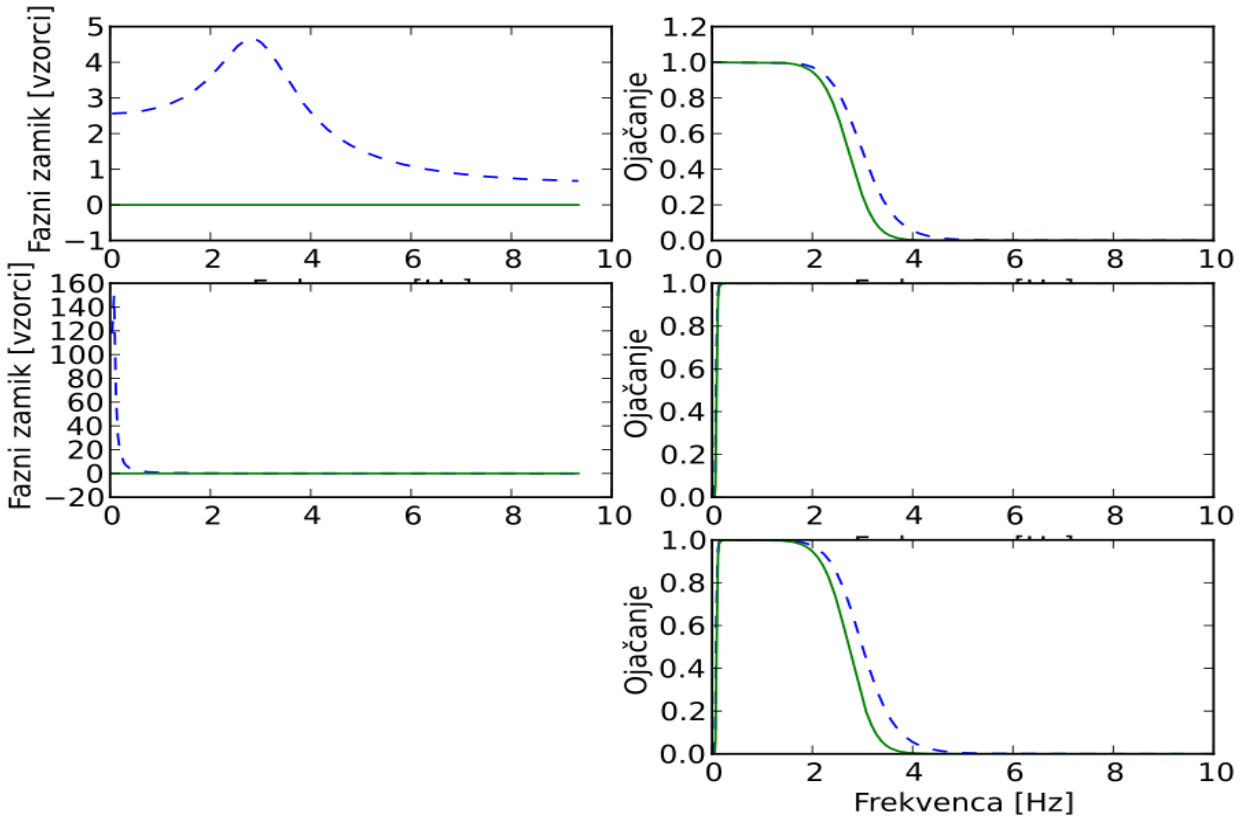
$$X(\omega) = \sum_{n=-\infty}^{\infty} x[n]\, e^{-j\omega n}$$

$$x[-n] \leftrightarrow X^*(\omega)$$

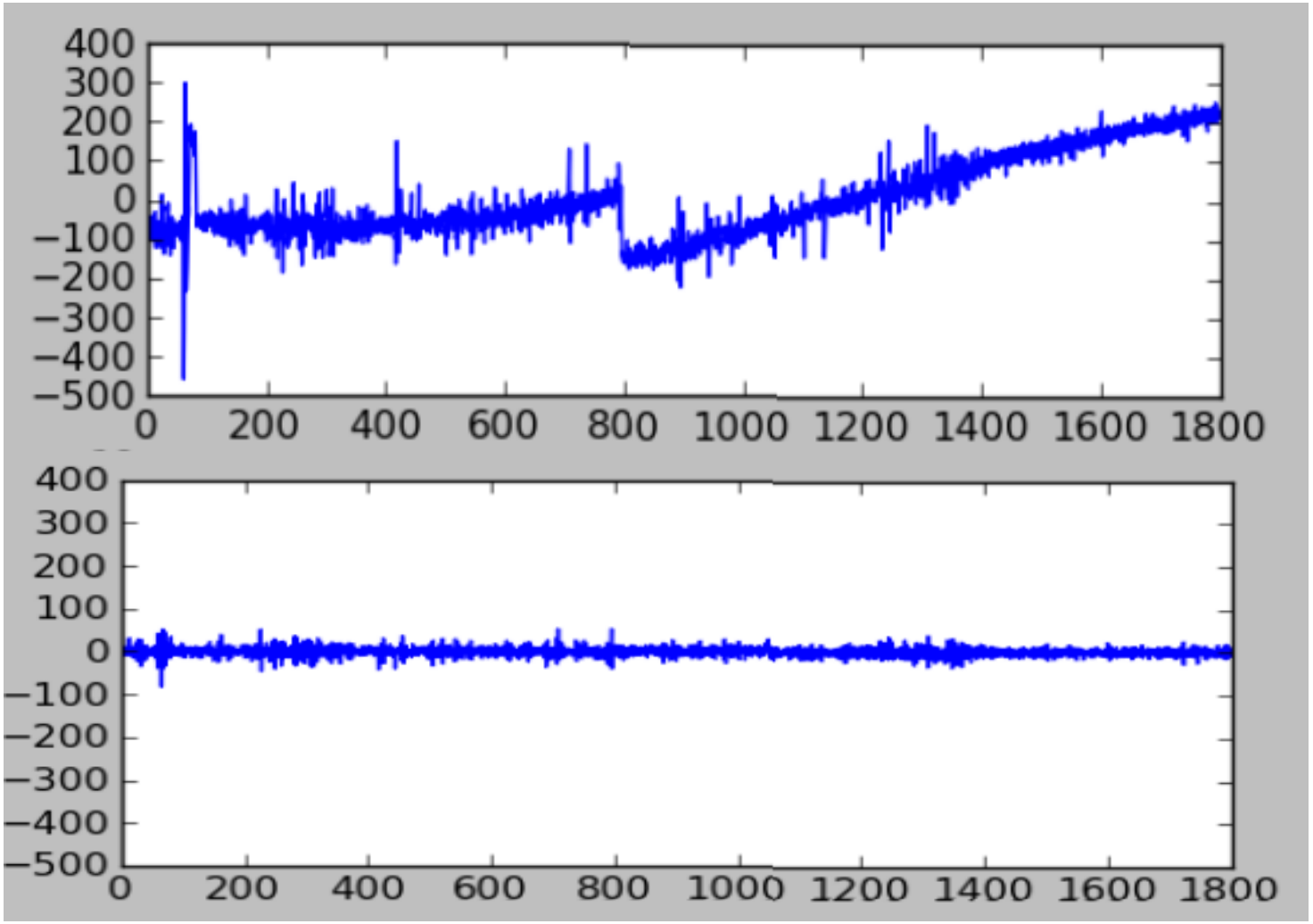
$$S(\omega) = Z_2^*(\omega) = H^*(\omega)\, Z_1(\omega)$$
$$= H^*(\omega)\, H(\omega)\, X(\omega)$$
$$= |H(\omega)|^2 X(\omega)$$

Preprocessing

- Phase and amplitude response of the 4-th pole Butterworth band-pass filter with the pass-band from 0.08 Hz – 3.0 Hz with and without double-pass filtering scheme

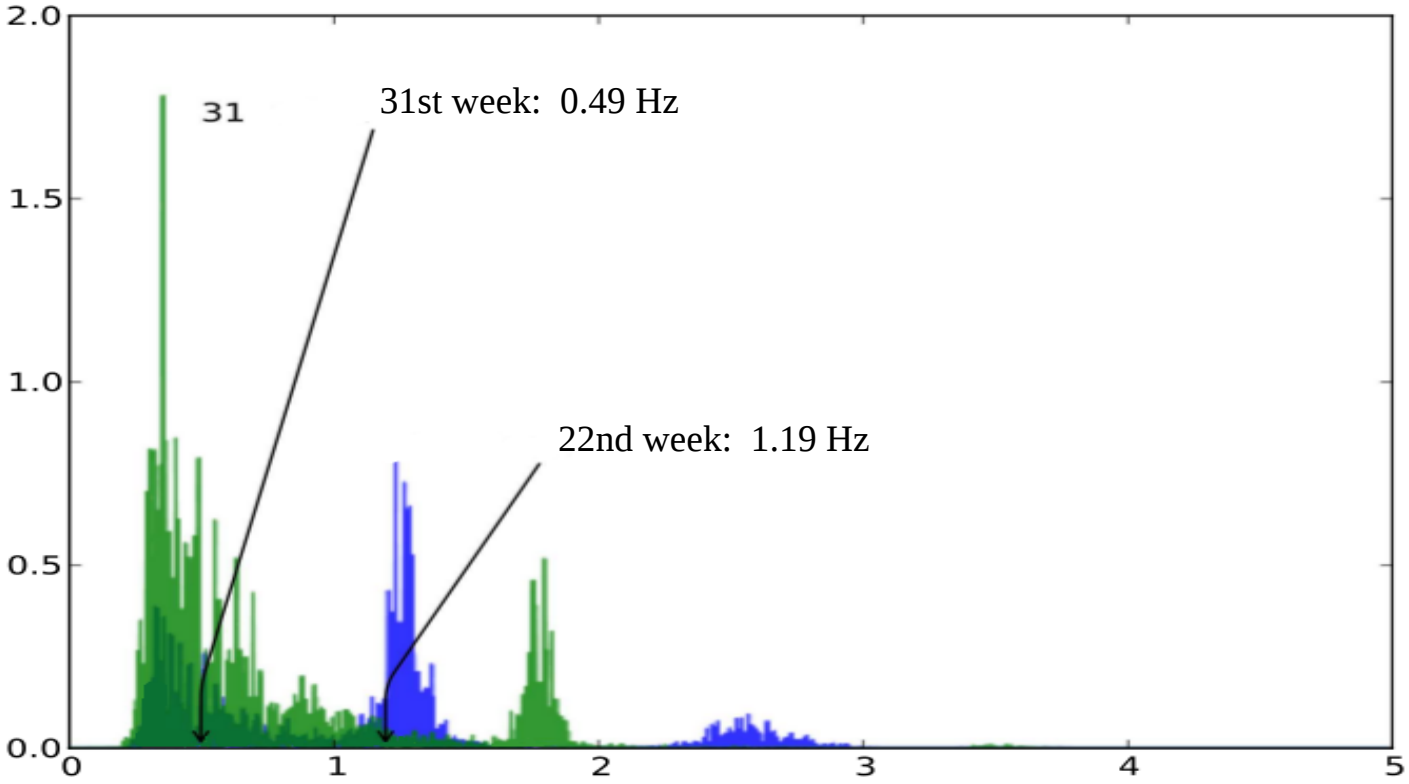


Preprocessing



Behavior of signal power spectrum during pregnancy

- Changes of power spectrum and median frequency during pregnancy for a selected record. The spectrum is moving to the lower frequencies

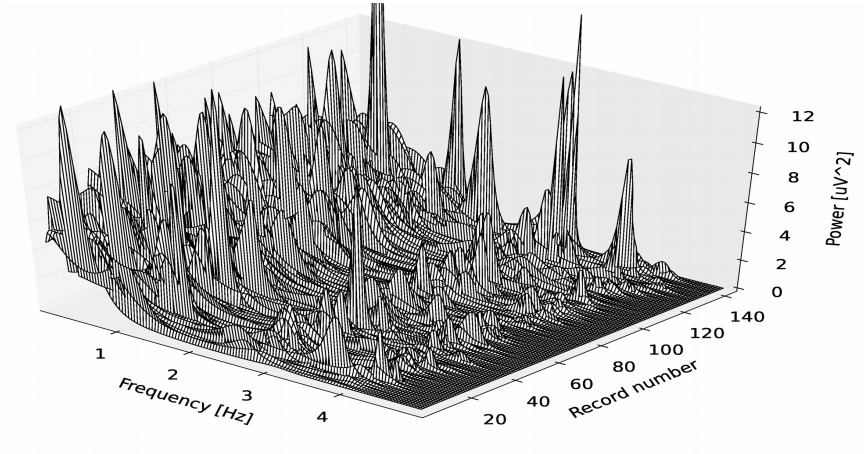


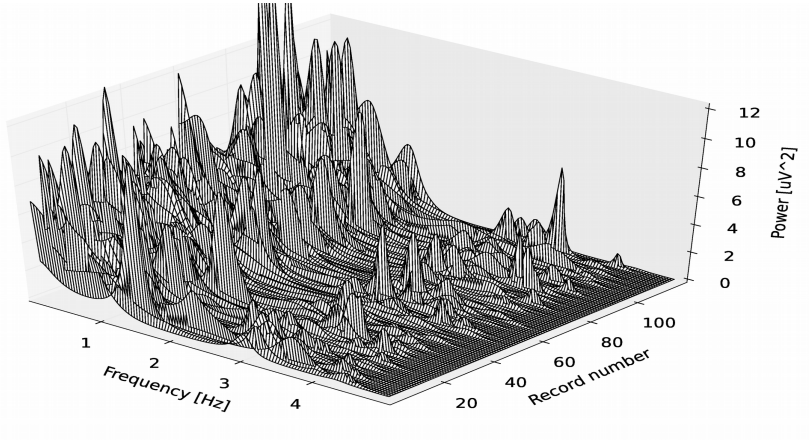
Signal power spectra of term and pre-term delivery records

Recorded early (143)

Term delivery

Recorded late (119)

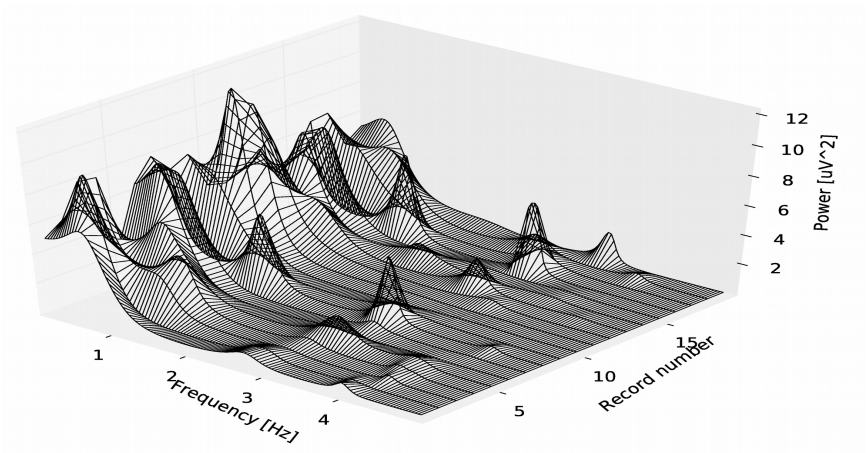


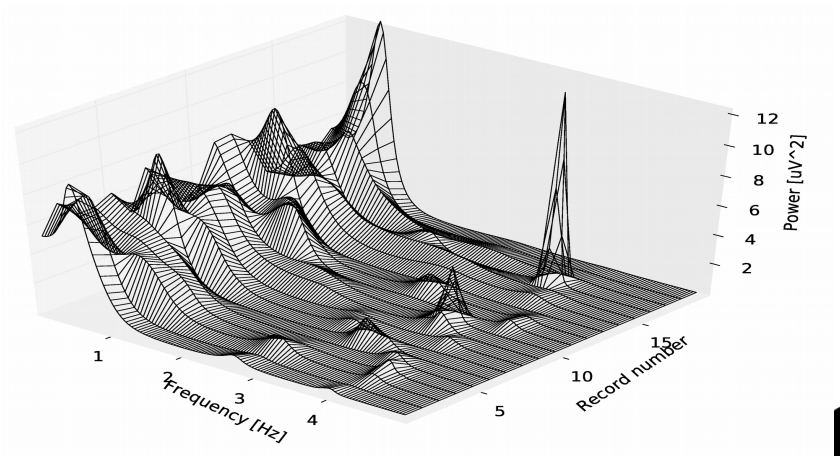


Recorded early (19)

Pre-term delivery

Recorded late (19)



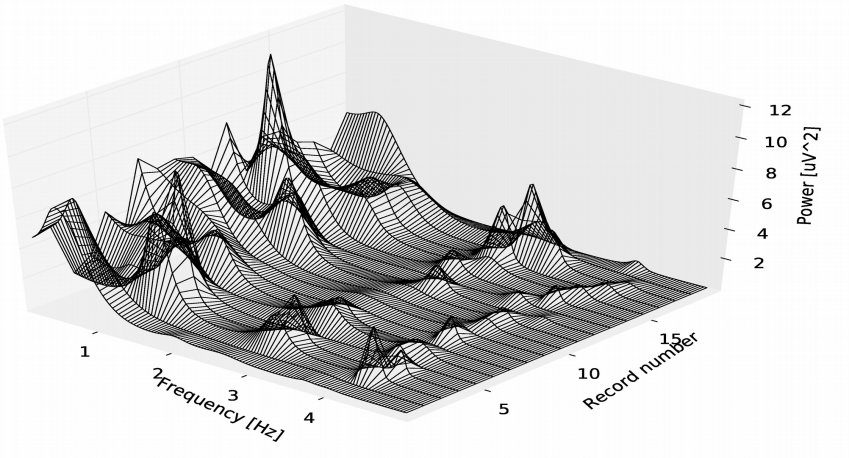


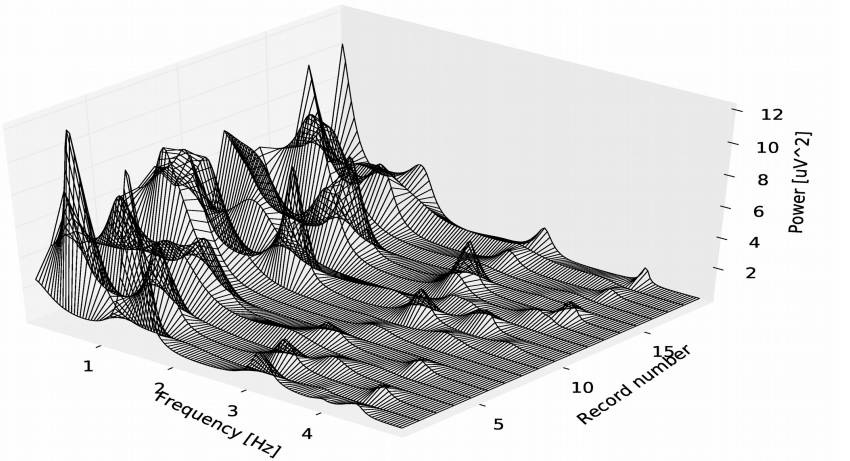
Signal power spectra of term and pre-term delivery records

Recorded early (19 random)

Term delivery

Recorded late (19 random)

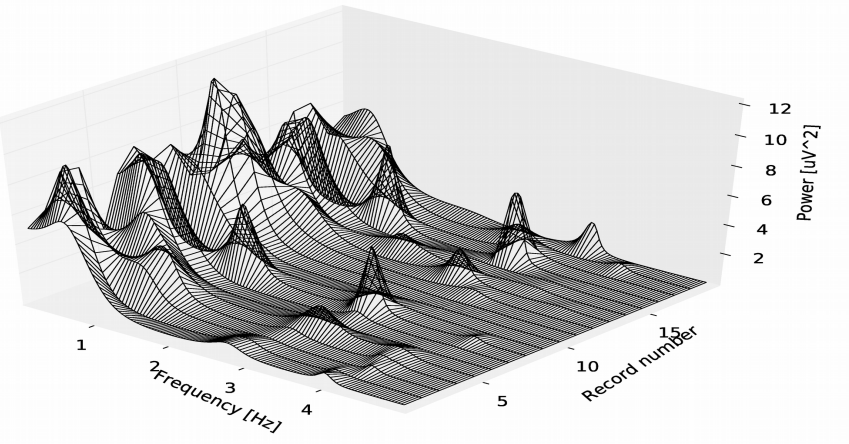


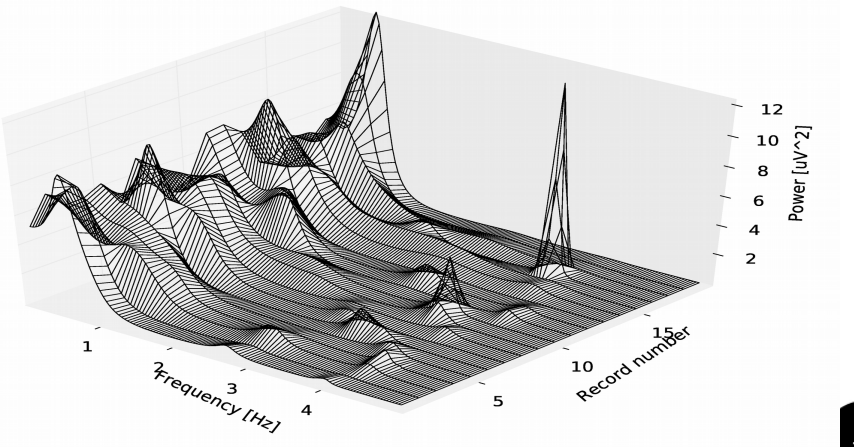


Recorded early (19)

Pre-term delivery

Recorded late (19)



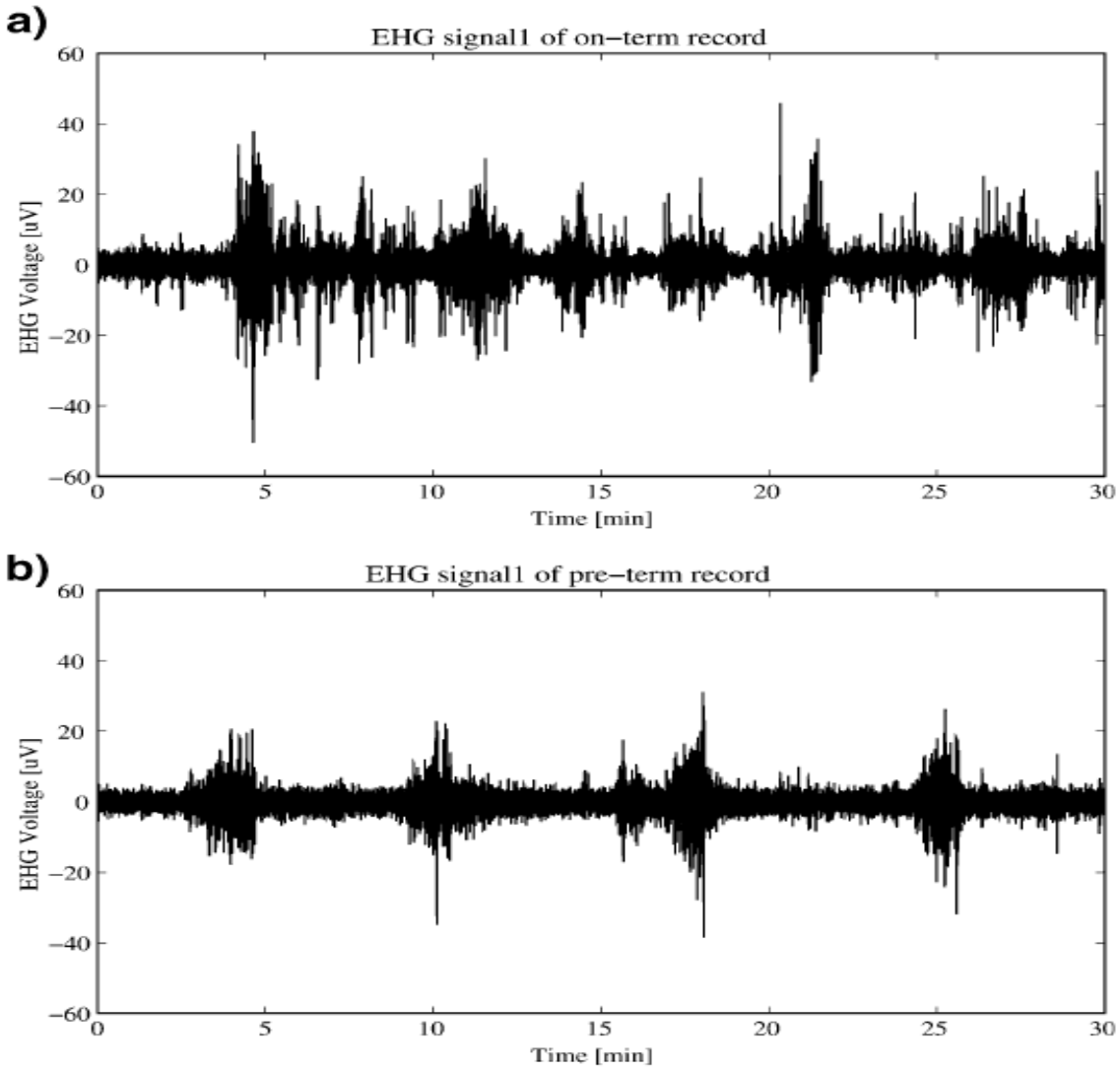


Hypotheses

- Characteristics and changes of power spectra of signals of electrical activity of uterus may indicate the pre-term delivery
- Techniques to estimate characteristics of power spectra
  - Peak frequency of power spectrum
  - Peak amplitude of power spectrum
  - Median frequency of power spectrum
  - (Coherence function to estimate similarity of power spectra)

Characteristics of signals of term and pre-term delivery records

- a) Signal 1 of a term delivery record (recorded in 30th week, delivery in 39th week)
- b) Signal 1 of a pre-term delivery record (recorded in 30th week, delivery in 32nd week)
- The signal of the pre-term delivery record shows higher predictability than that of the term delivery record



Biological systems

- Since a biological system is composed of billions of intricately interconnected cells whose responses are non-linear, it may be regarded as a complex, non-linear dynamic system
- The underlying physiological mechanisms of biological systems are non-linear processes
- Non-linear signal processing techniques seem appropriate quantitative tools and are applicable to measure the variability of underlying physiological mechanisms of biological systems and to analyze their outputs

Hypotheses

- The nature of electrical activity of the uterus suggests the use of non-linear signal processing techniques which estimate, e.g.,
  - regularity of finite length time series
  - periodicity of time series
  - the amount of chaos in a system
  - the complexity of time series

Non-linear signal processing techniques

- Sample entropy (is a measure of regularity of finite length time series and estimates the extent to which the data did not arise from a random process)
- (Autocorrelation zero-crossing (estimates periodicity of time series))
- (Maximal Lyapunov exponent (estimates the amount of chaos in a system))
- (Correlation dimension (estimates the complexity of time series))

(Term Pre-term EHG DataBase (TPEHG DB))

Characteristics of the groups of EHG records

Group	*N*	Recording	Birth	Parity	Age
≥37 weeks, *early*	143	22.7	39.7	0.49	29.7
≥37 weeks, *later*	119	30.8	39.6	0.52	30.1
<37 weeks, *early*	19	23.0	34.2	0.39	29.6
<37 weeks, *later*	19	30.2	34.7	0.64	29.2

N number of records, *recording* average term of recording (weeks), *birth* average term of birth (weeks), *parity* average number of prior pregnancies, *age* average age (years)

(Linear and non-linear signal processing techniques)

- For a linear function, *f(x)*, the following holds:

$$f(x+y) = f(x) + f(y)$$

$$f(a.x) = a.f(x)$$

- Even though the Fourier transform is a linear operation, computing the power spectrum, *P*, is not a linear technique

$$P(x(t) + y(t)) \neq P(x(t)) + P(y(t))$$