Signals and Systems program and organization

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- organization
- goals
- motivation – examples of signal processing
- program of the course
- literature
- assessment

Web-pages

http://www.fit.vutbr.cz/study/course-l.php?id=6304

http://www.fit.vutbr.cz/~hubeika/ISS

Organization of the Course

- 2 lecture groups, 1 lecture per week, 3h.
- computer labs 1 in 14 days, 2h.
- project

Who will be teaching ?

Lectures - Valentina Hubeika, Honza Černocký, Lukáš Burget.

Computer labs: Olda Plchot, Franta Grézl, Mirko Hanneman (EN), Valia Hubeika, Michal Mrnuštík, Miloš Janda

address / phone number / office can be found at www:

http://www.fit.vutbr.cz/~name

http://www.fit.vutbr.cz/~iname

Our Goals:

"Introduction to the theory of signals and linear systems both in continuous and discrete time domain. Introduction to the theory of random signals. We will pay special attention to the spectral analysis and linear filtering as these are principal components of modern communication systems."

Motivation

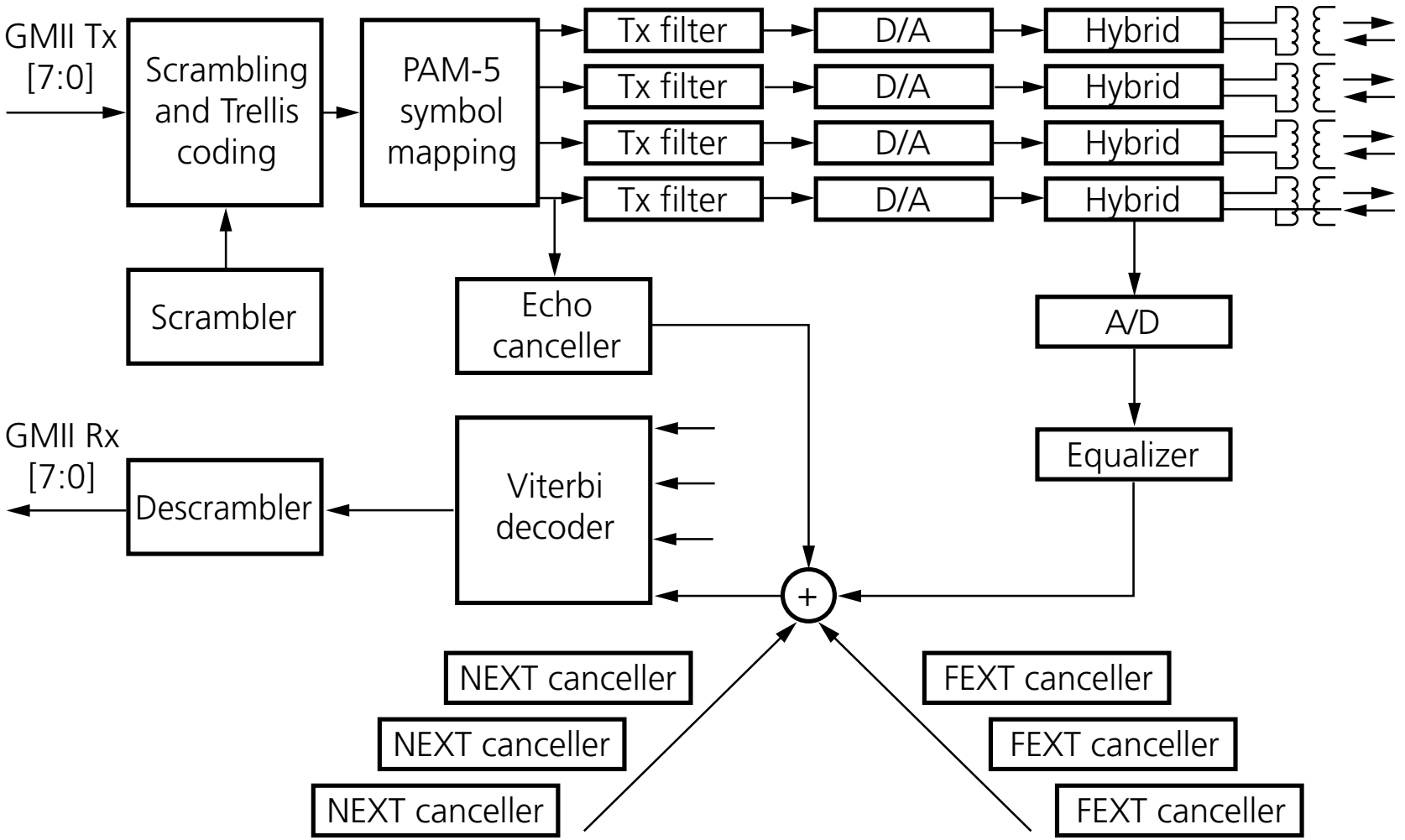
Just look around you ...

examples:

- gigabit Ethernet – encoded messages.
- MP3.
- finance !
- sound, picture, movie...
- mobile telephony.

1 Gb Ethernet - adopted from 3COM

FIGURE 16. Architecture of a 1000BASE-T Transceiver



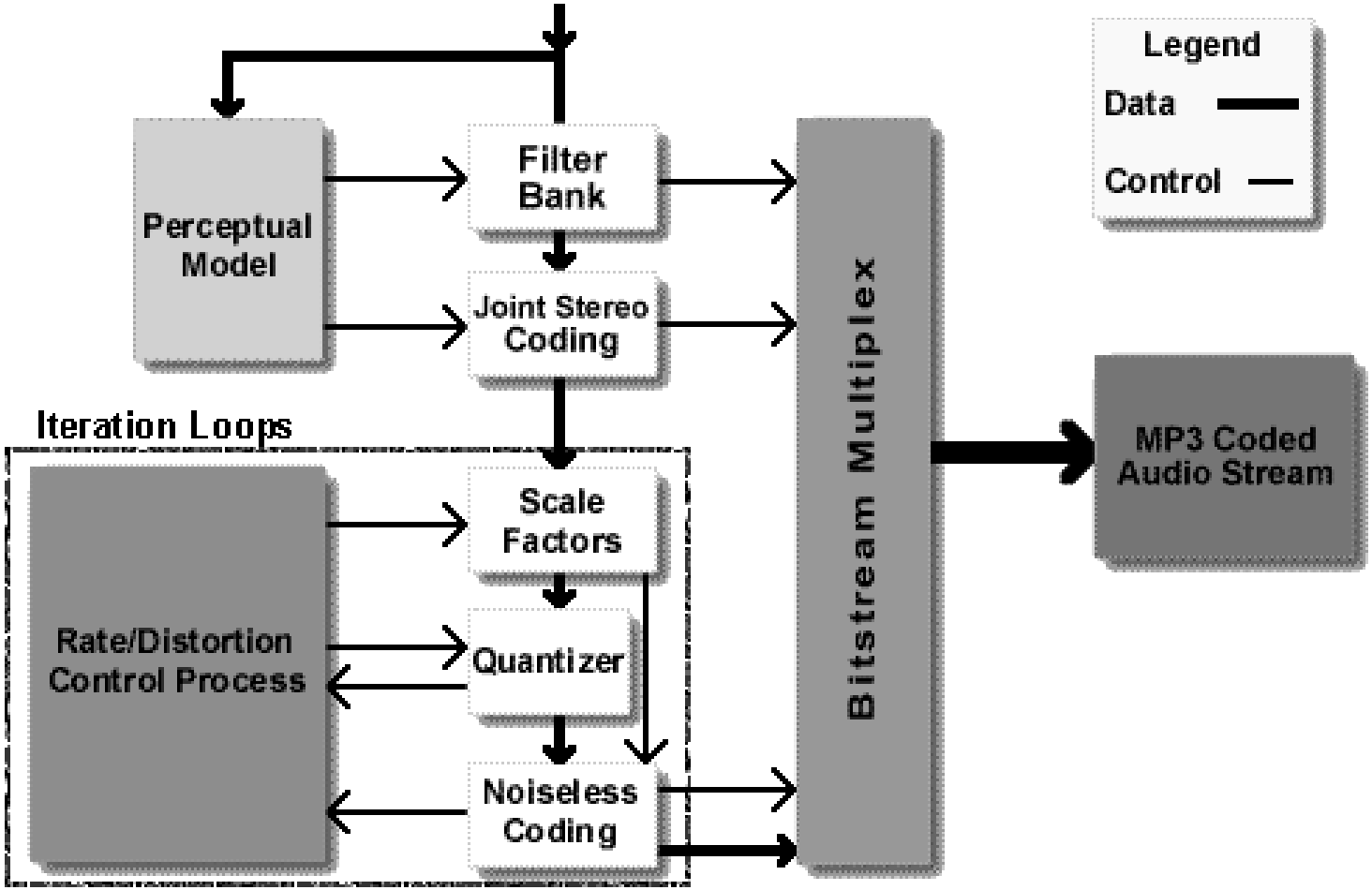
MP3, precisely MPEG2 Layer 3 – adopted from Frauenhofer Institut

sound quality	bandwidth	mode	bit-rate	reduction ratio
telephone sound	2.5 kHz	mono	8 kbps	96:1
better than short wave	4.5 kHz	mono	16 kbps	48:1
better than AM radio	7.5 kHz	mono	32 kbps	24:1
similar to FM radio	11 kHz	stereo	56...64 kbps	26...24:1
near-CD	15 kHz	stereo	96 kbps	16:1
CD	>15 kHz	stereo	112..128kbps	14..12:1

Example:

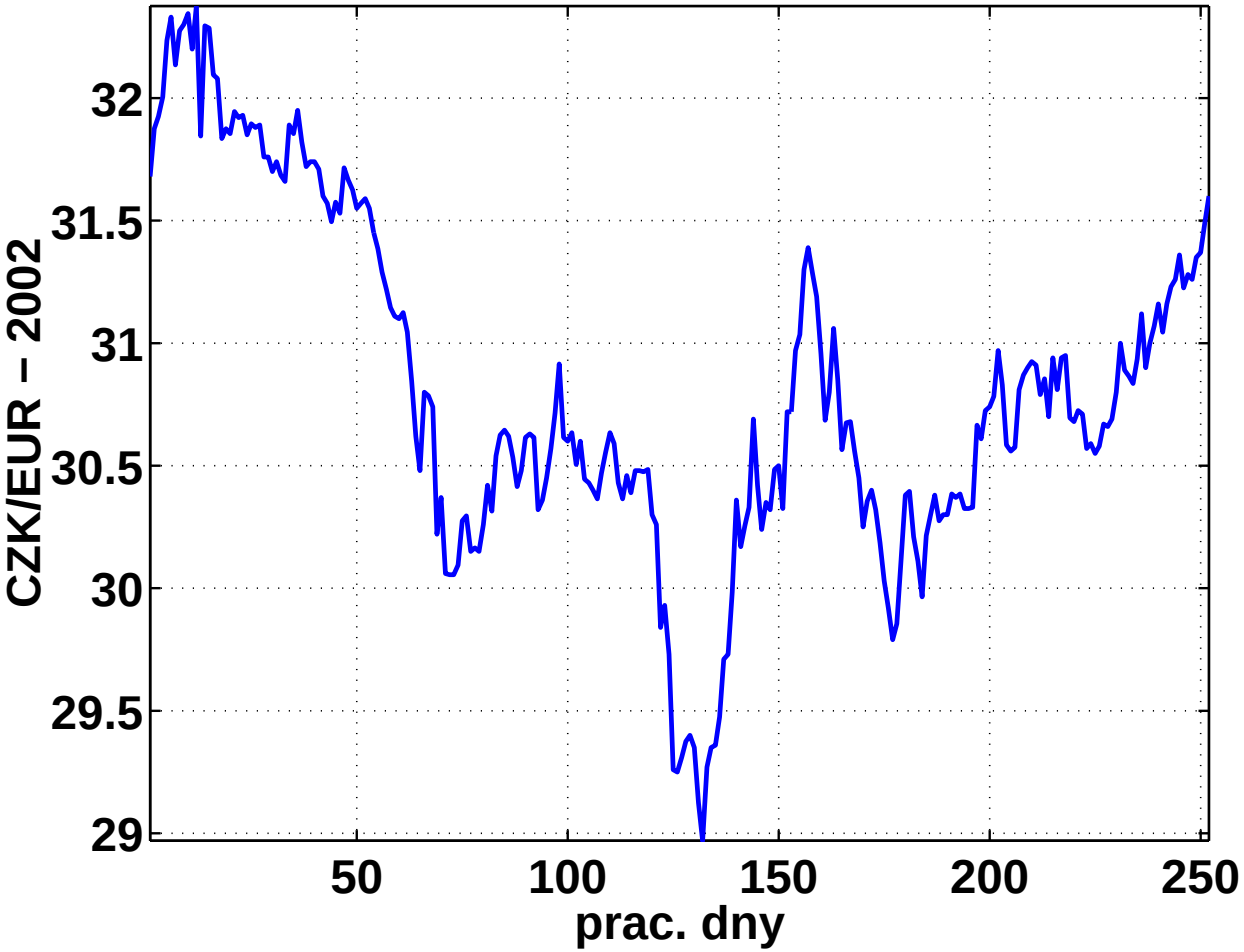
```
-rw-r--r-- 1 cernocky speech     62274 Feb 19 15:33 sinf.mp3
-rw-r--r-- 1 cernocky speech    674776 Feb 19 15:43 sinf.wav
```

$\Rightarrow$ "explanation" and a scheme



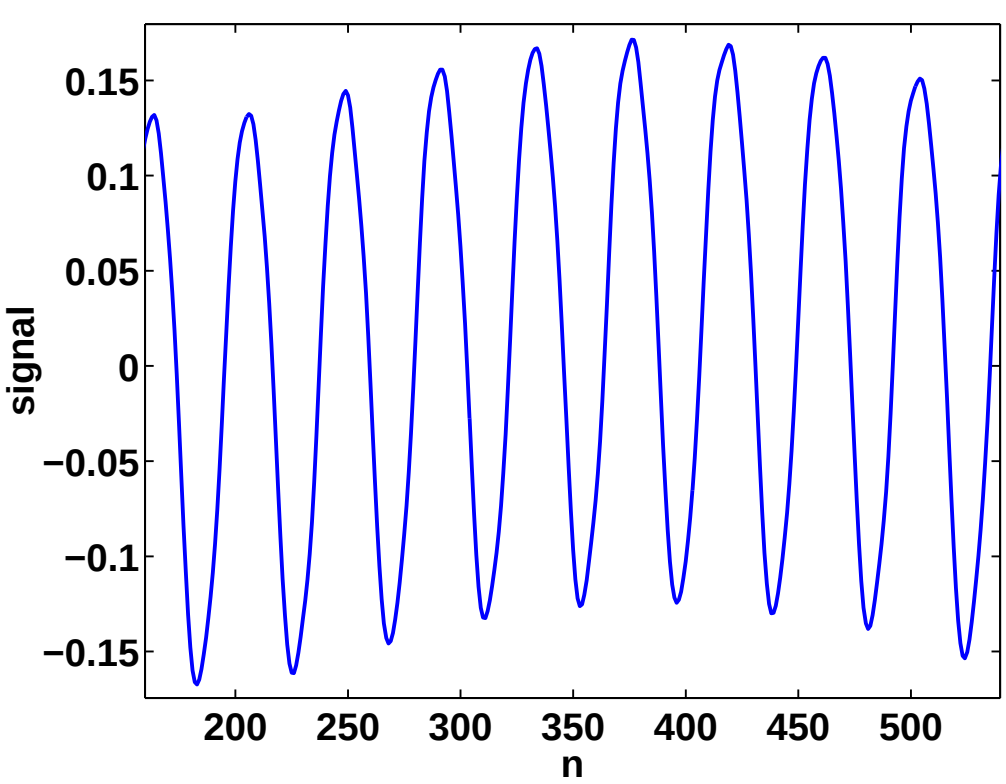
Finance – adopted from ČNB

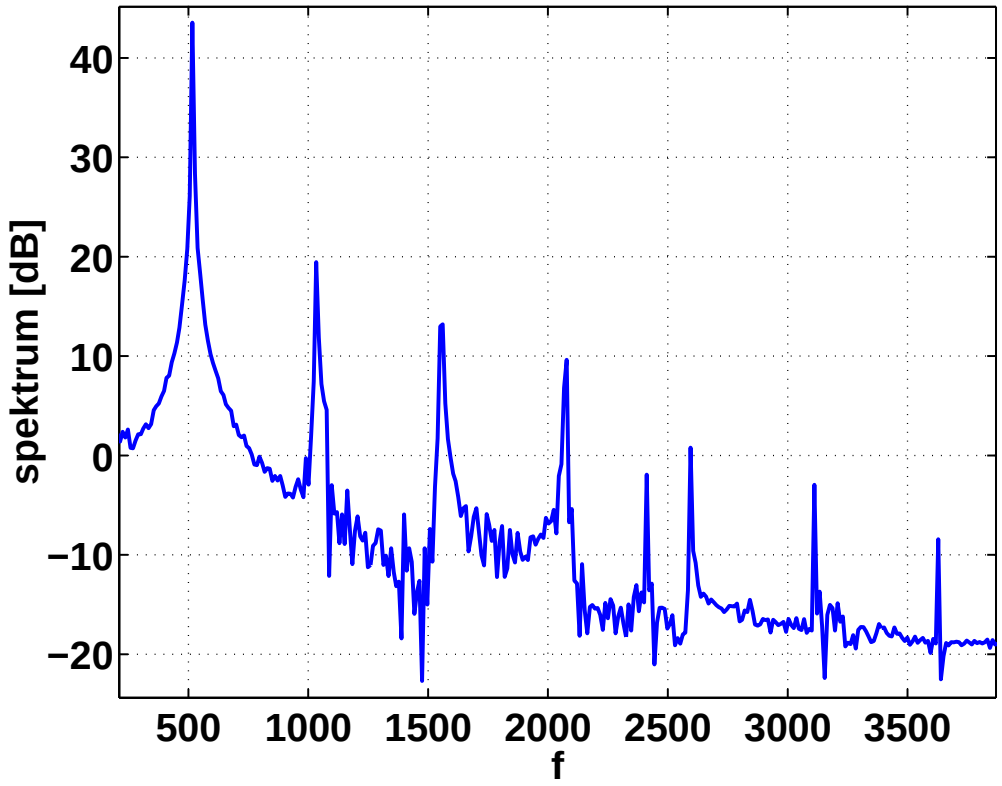
analysis in finance institutions such as banks, insurance companies, . . .



Spectrum of a signal from a soprano flute

```
s = wavread('SIG/out.wav'); x = s(7100:9147); X = fft(x);
f = (0:1023)/2048 * 44100 /2; plot (f, 20*log10(abs(X(1:1024))));
```



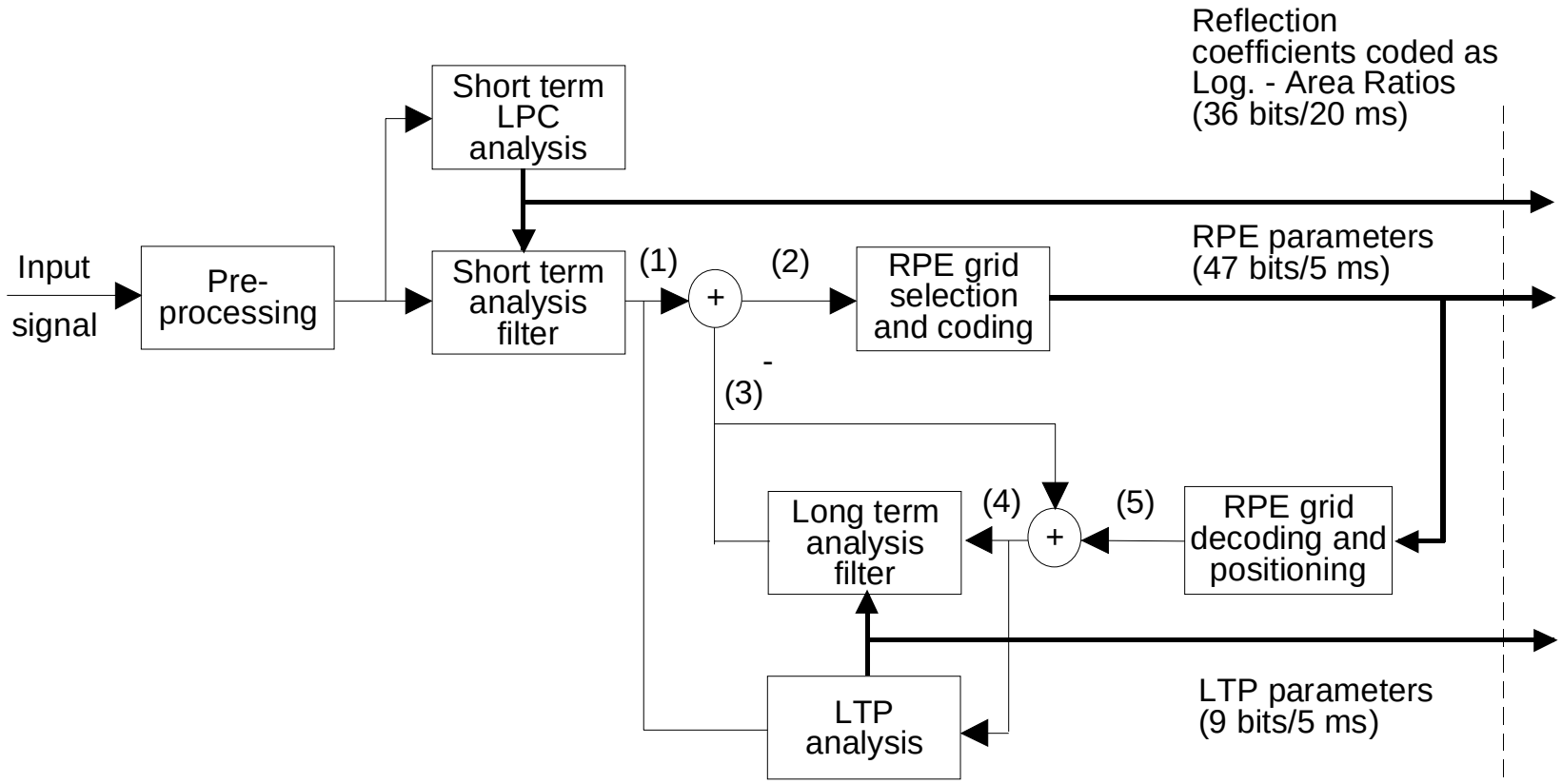


Playing on the frequency 517 Hz. What tone is it ?

a1=440Hz, the shift between the tones is $q = \sqrt[12]{2}$, $440 \times q^3 = 523$ . . . which means its c2

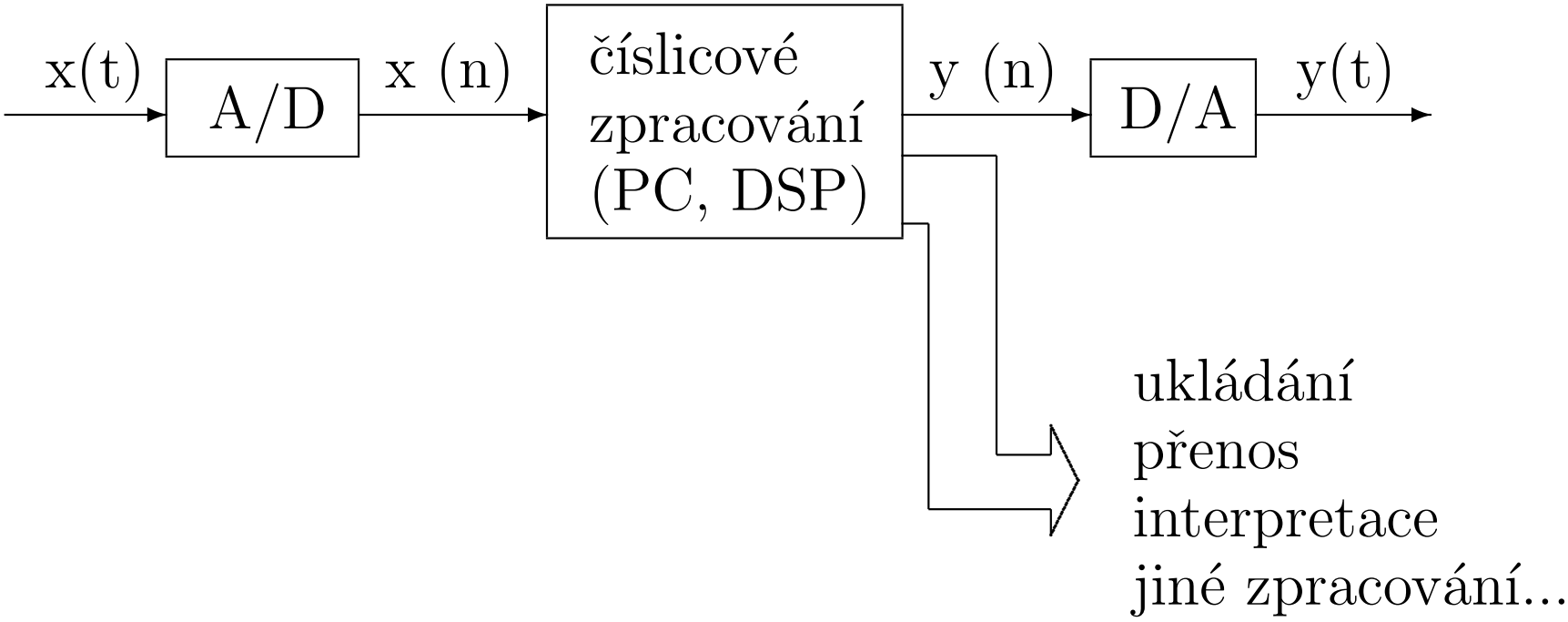
this is pretty low . . . there is much more that just 517 Hz!!.

Speech coding in mobile phones 13 kbit/s – adopted from ETSI



(1) Short term residual
(2) Long term residual (40 samples)
(3) Short term residual estimate (40 samples)
(4) Reconstructed short term residual (40 samples)
(5) Quantized long term residual (40 samples)

How and why digital processing is done – "historical slide":



- reproducibility.
- no quality degradation due to material aging.
- no difficult setup.
- possible adaptive processing ("appliance alternate its behaviour depending on the input signal").
- simulation =¿ application.
- IT, Internet, mobile telecommunication.

Organization of the lectures

everything on the web-page, all "aux.m" files are available as well

1. Introduction, motivation, organization of the course.

   Examples of real signal processing systems.

   Basic signal classification - continuous/discrete time, periodic/non-periodic signals.

   Time axis transformation.
2. Simple continuous and discrete periodic signals: sine and complex exponential.

   Requisite basic information on complex numbers.

   Discrete and continuous systems.

   Linear time-invariant systems (LTI).

   Representation of a signal as a series of impulses, convolution.

   Definition of systems by means of differential and difference equations.

3. Continuous signals and their representation in frequency domain:

   Periodic - Fourier series (FS), Fourier coefficients.

   Non-periodic - Fourier transform (FT), spectral function.

   Spectra of some characteristic signals.

   Energy of a signal - Parseval theorem.

4. Continuous systems - Laplace transform, transfer function, frequency characteristic, stability. (Example on a simple analog circuit.)

5. Sampling and reconstruction - ideal sampling, aliasing, sampling theorem.

   Spectrum of a sampled signal, ideal reconstruction.

   Normalized time and frequency.

   Quantization.

6. Discrete signals and their frequency analysis - discrete Fourier series (FS), Discrete Time Fourier Transform (DTFT).

   Circular convolution.

   Discrete Fourier Transform (DFT).

   Fast Fourier Transform (FFT).

7. Discrete systems - z-transform, systems with finite and infinite impulse response (FIR a IIR), transfer function, frequency characteristics, stability.

   Example of a digital filter: MATLAB and C.

8. Discrete systems, follow-up: design of simple digital filters, sampling of frequency characteristic, windows.

   Connection between the continuous and discrete time systems.

9. Two-dimensional (2D) signals and systems: spatial frequency, spectral analysis (2D-Fourier transform), mask filtering.

   Example - JPEG.

10. Random signals - random variable, realization, distribution function, probability density function (PDF).

    Stationarity and ergodic property.

    Parameters of a random signal: mean value, etc. and their estimation - over population and over time.

11. Random signals, follow-up: Correlation function, power spectral density (PSD).

    Passing a random signal through an LTI system.

12. Summary. Demos, what is done at the DCGM :

    - computer graphics for medicine,
    - “classical” computer graphics,
    - image and video processing,
    - natural language processing,
    - speech signal processing.

    You want to know more ? See:

    `http://www.fit.vutbr.cz/units/UPGM/`

    `http://speech.fit.vutbr.cz`

    Try `http://speech.fit.vutbr.cz/lid-demo`

Computer Labs Programme

Groups for computer labs are formed by means of the online registration in WIS.

1. MATLAB - essentials, reading and writing of a sound and image signal. Graphical plot and export in Matlab.
2. Fourier analysis - decomposition of a signal into components (basis), from a simple example to a practical problem. Why complex numbers are so important.
3. Sound - octave equalizer, analysis and processing of sound.
4. Graphics - image processing - focusing, bluring, edge detection. DCT coefficients in the JPEG.
5. Random Signals - mean value, standard deviation, distribution function, probability density function. Tools.
6. Sampling. Quantization. Aliasing.

Project

Everybody works individually:

- Analysis of a signal, sampling effect.
- upload of your own random signal.
- computing of parameters.
- all in IS, automatic evaluation.

Literature

- http://www.fit.vutbr.cz/~cernocky/sig
- Oppenheim A.V., Wilski A.S.: Signals and systems, Prentice Hall, 1997.
- Jan, J., Kozumplík, J.: Systémy, procesy a signály. Skriptum VUT v Brně, VUTIUM, 2000.
- Šebesta V.: Systémy, procesy a signály I., Skriptum VUT v Brně, VUTIUM, 1997.

Controlled attendace:

- Lectures are free
- Attendance of the labs is not compulsory, BUT you get 2 points (of course a pretty smile isn't enough, be active).

assessment

- computer labs : each worth 2 points, overall 12 points.
- midterm exam, no literature neither notes nor calculator are allowed , 25 points.
- project - 12 points.
- final exam - 51 points, no literature neither notes nor calculator are allowed, a list of essential equations will be provided. The minimal number of points obligated be obtained during the exam is 17. Otherwise no points will be assighn to the student.

Video

- Czech and english lectures are to be streamed and the records stored.
- Look also at `http://prednasky.com`
- BUT:

"The provided video is to serve for those who cannot attend the lecture and as the study aid during the preporation for the exams. For a large number of students, the records are the only source of information to the course. Many practise watching the lectures only just before the exam which results to the poor knoledge during the state exam. Unfortunatelly, this happens not only in the ISS course. Thus, we would like to kindly call everybody to the lectures."

Note:

- **Report errors in the slides or any other material provided.**
- **Suggestions, improvements, complains are welcomed !**