

# Feature extraction from 3D spectra of electrophysiological signals

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*Abstract – The aim of this study is to demonstrate visualization and extraction of signal spectral features via 3D spectroscopy. 3D spectroscopy is important in identification of the short lasting spectral features and their characteristics in time and frequency domain.*

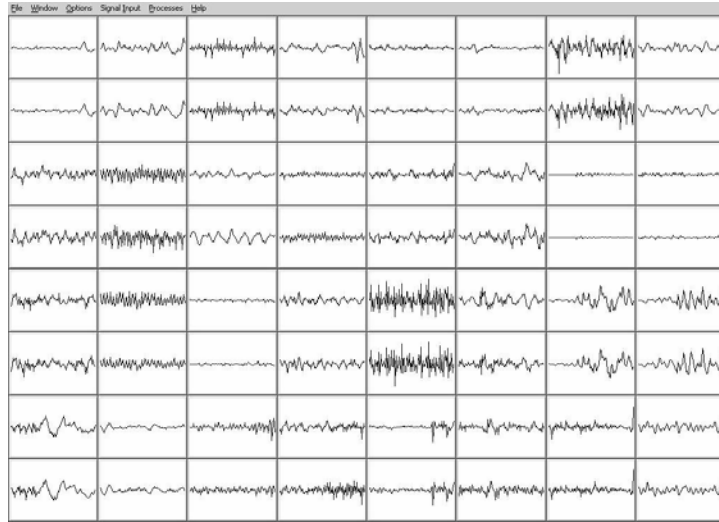
*Those advantages of 3D spectroscopy are demonstrated in this study on particular neurophysiologic experiments. These experiments included acquisition and analysis of various electrophysiological signals ranging from rat and human EEG signals to acoustic and blood pressure signals.*

*Usage of specific methods of signal analysis like cross spectra was also demonstrated.*

## 1. Introduction

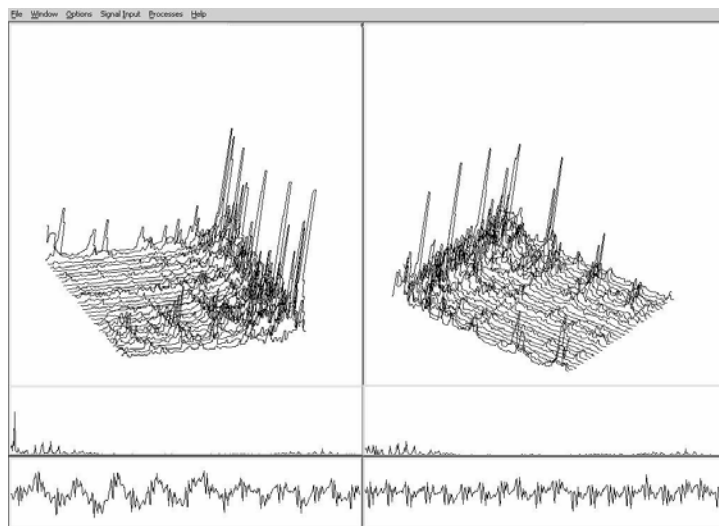
Spectroscopy is recently present in analysis of biomedical signals. Most analysis are performed by computing mean power spectra of analyzed signals while newer methods introduce usage of time dependent discrete Fourier transform. With latter approach it is possible to extract and visualize short lasting signal features which are lost in “averaging” of mean power spectra approach.

The Group for Intelligent Systems (GIS) has developed various systems for acquisition, monitoring and analysis of biomedical signals explained in some details in [3], [5], [6], and [7]. These include neurological, EEG, cardiologic and neuroacoustic signals.



*Fig 1. Monitoring of 64 channels.*

Systems can perform various methods of signal analysis that include arithmetic operations on input signals, computation of time dependent Fourier transform and cross-spectra.



*Fig 2. 3D Spectroscopy example.*

After computation, 3D representation of time dependent FFT can be displayed (figure 2). This provides 3D spectroscopic approach in signal analysis.

GIS systems were used in numerous biomedical experiments providing signal acquisition and analysis.

The aim of this study is to demonstrate visualization and extraction of signal spectral features via 3D spectroscopy.

## 2. Methods

In this study we used data obtained from various biomedical experiments including EEG signals of rat brain, human EEG signals, blood pressure signals of rats in various physical conditions etc.

Systems are based on Personal Computer with peripheral signal acquisition card as shown on figure 3.

Systems can support various peripheral cards. These are Innovative Integration DSP embedded systems based around Texas Instruments DSP chips (TSM320C3X and TSM320C6X series), simple signal acquisition systems (like Burr Brown ED428) and even PC soundcards (using their line input).

Systems can perform multichannel signal acquisition at high sampling rates of up to 100KHz and if needed, 1MHz range with Innovative Integration m62 peripheral cards. Signal analysis depends on particular experiment but in most cases it was based on computing time dependent Fourier transform and cross spectra of multiple signals in the experiment.

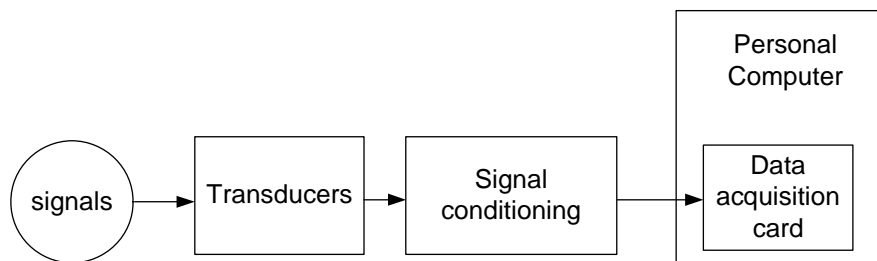


Fig. 3. Schematics of signal acquisition system.

## 3. Results and discussion

In one experiment, acquisition system was used for recording EEG signals from rat brain (figure 4). Signals were amplified and A/D conversion was performed at sampling rate of 30KHz. As shown in Figure 4 signal consists of neural pulses and noise like intervals between pulses.

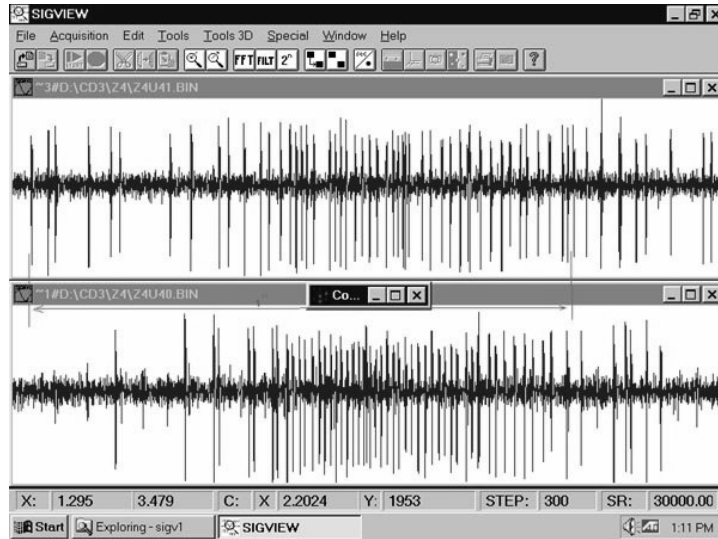


Fig 4. EEG signals of rat brain. Interval that is marked represents one second.

The Figure 5 represents enlargement of previous image down to single pulses. Form of the signal suggests that sampling frequency may be adequate but signal should be sampled at much higher rate in order to determine exact bandwidth of EEG signal.

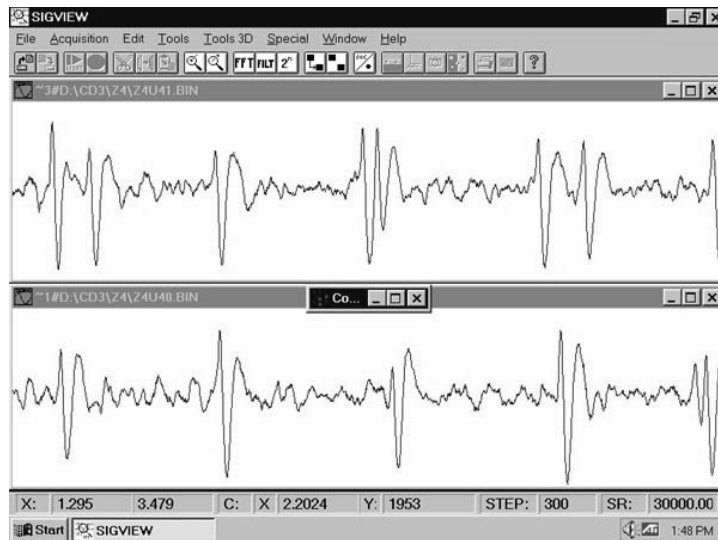


Fig 5. Enlarged graph showing form of neural pulses.

Another example (figure 6) is spectroscopy analysis of whale song. In upper right corner is enlarged part of spectrogram.

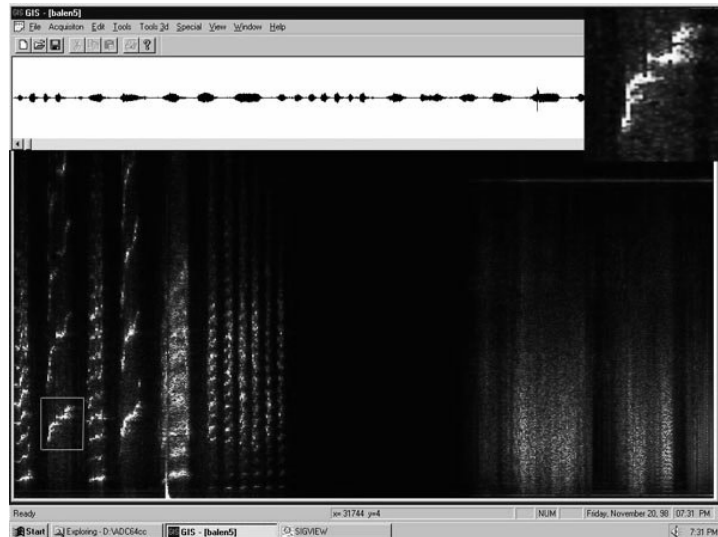


Fig 6. *Spectrogram of whale song signal. Frequency scale is vertical with lower frequencies on bottom and time scale is horizontal (right is recent). Amplitude of spectral components is described with brightness.*

It displays a shift of tone's base frequency through a time interval.

Example demonstrates identification of spectral features by analysis of spectrogram. This kind of visualization is important in identification of the short lasting spectral features. In this case we can identify tone which frequency shifted up almost twice (one octave).

Usage of cross spectra is demonstrated in next experiment. Acquisition of four EEG signals of human brain is performed at sampling rate of 30KHz. Signals are recorded and analysed by computing time dependent Fourier transform. Lower frequency regions of spectra are displayed separately.

Cross spectra is formed by multiplying the same FFT coefficients of four spectra. Thus spectral lines that are identical for all four spectra are distinguished from independent lines. In this way spectral features common for all signals can be identified.

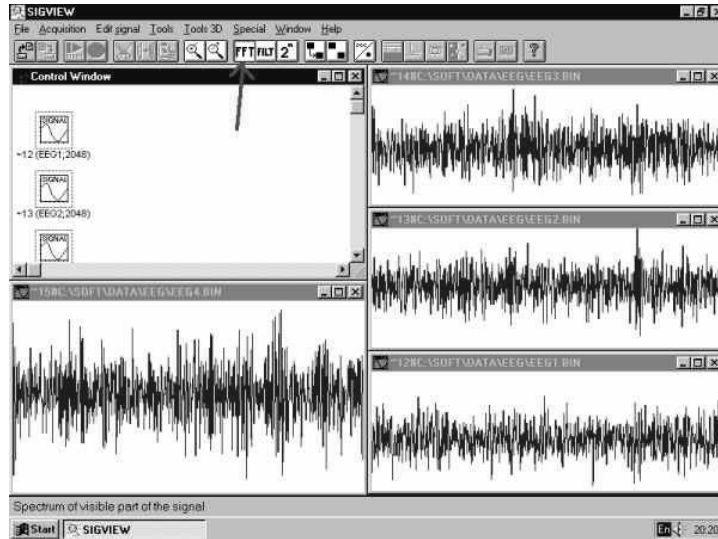


Fig 7. Four EEG signals of human brain.

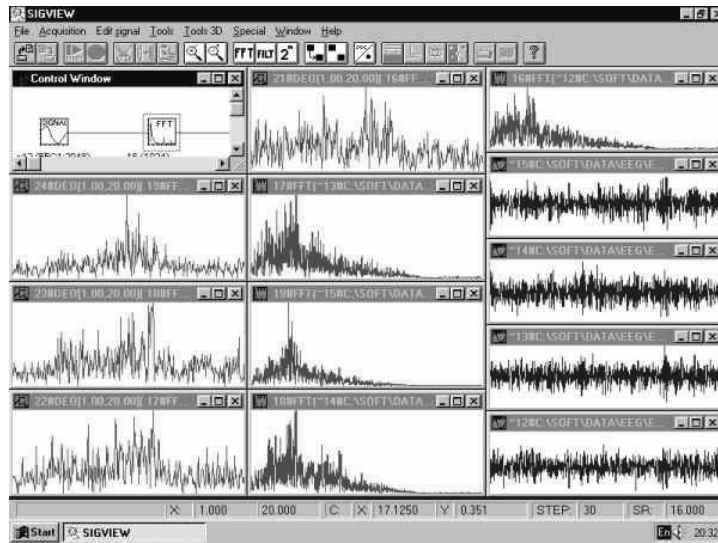


Fig 8. Lower part of signal spectra is shown on left side of window. Whole spectra is in the middle and EEG signals are displayed on the right side.

Figure 9 represents 3D view of common spectral feature. This visualization is helpful in identification of feature changes in frequency and time domain.

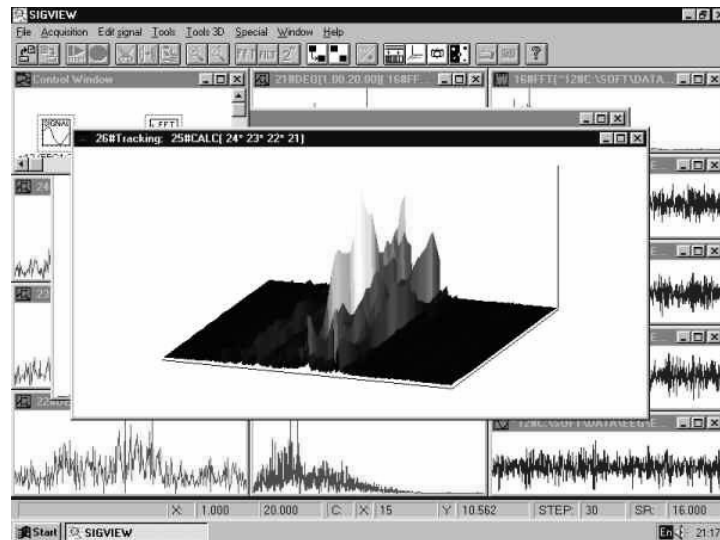


Fig 9. 3D representation of cross spectra which represents common spectral feature.

Connection between specific spectral features and health state of tested subject is demonstrated in next experiment. Acquisition of blood pressure signal of two animals was performed [7]. Figure 10 represents blood pressure signals and their spectra while figure 11 represents 3D representation of time dependent Fourier transform. On figure 11 we can notice very low frequency (VLF) component of the signal and very faint component in low frequency (LF) region. There is intensive component in high frequency (HF) region which represents so called “respiratory line”.

3D spectroscopy is a helpful tool for identification of time and frequency changes of spectral formations. This is visible on “respiratory line” on figure 11.

Moments of forming and disappearance of spectral formations can also be identified.

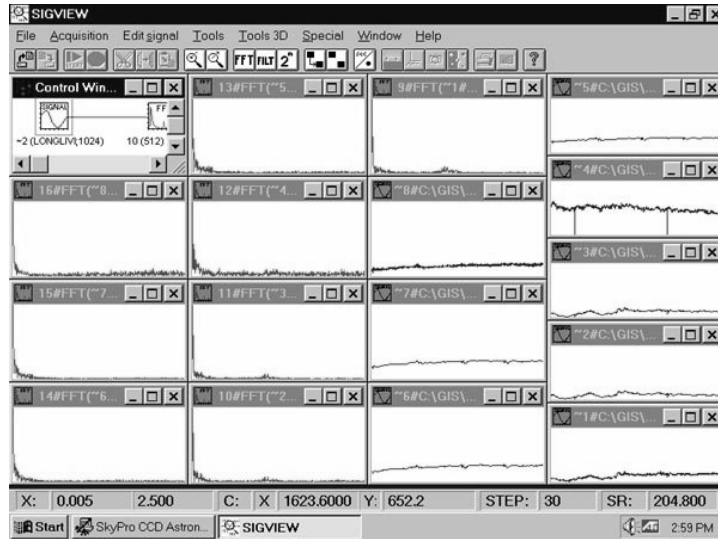


Fig 10. Blood pressure signals of two animals (right side, blue graphs) and their spectra (left side, red graphs).

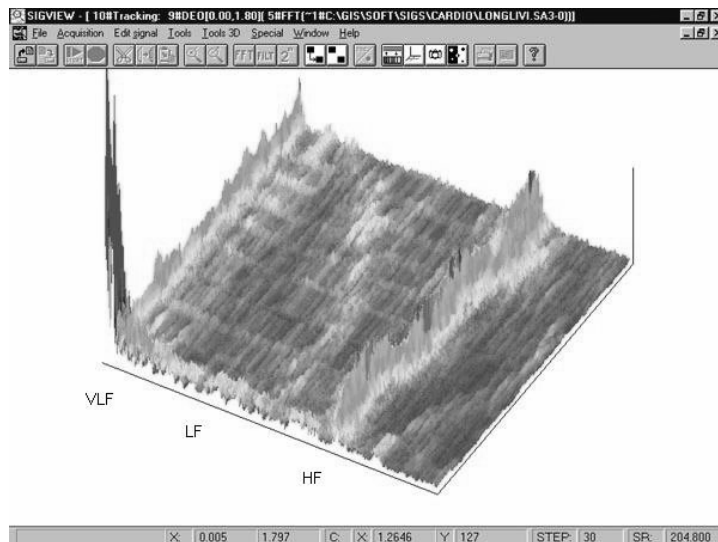


Fig 11. 3D representation of time dependent Fourier transform of blood pressure signal.



Finally figure 12 represents spectrograms of blood pressure signal. Left spectrograms represent normal animal and right one that did not survive.

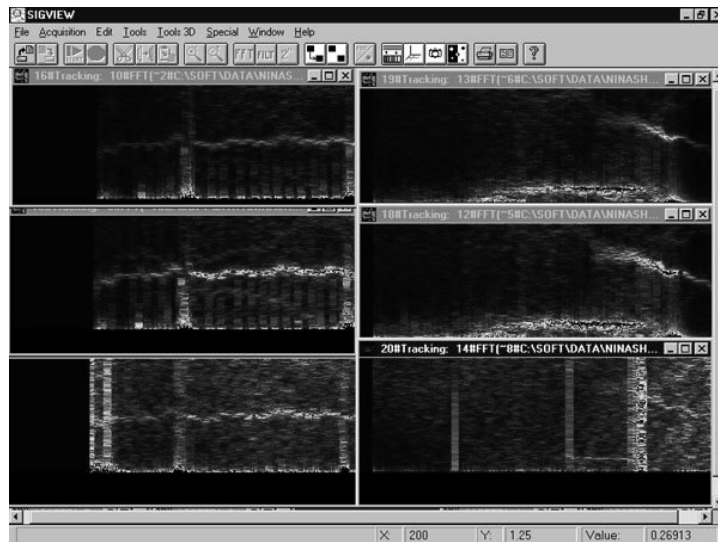


Fig 12. *Spectrograms of blood pressure signals. Spectrograms of normal animal are on the left side and spectrograms of animal that didn't survive are placed on the right side.*

We can notice complete absence of respiratory line in spectrograms of second animal trough the whole experiment. Also VLF components are shifted to higher frequencies. In the end of experiment spectral feature is forming near position of “respiratory line”. This suggests that certain spectral features can be connected with physical state of animals in the experiment.

## CONCLUSION

3D Spectroscopy introduced new ways of signal spectral features visualization and extraction. Spectral features and their characteristics like time and frequency changes can be easily identified. This approach in signal analysis can also be useful in design of feature recognition software.

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