Description for the general public

A number of phenomena in the world around us occur in the form of oscillations expressed in the sinusoidal function form – these are mechanical oscillations, acoustic oscillations, electric oscillations, and others, such as those describing pendulum motion, a single musical tone and vibrations of a resonance circuit. In practice, complex vibrations, which are the result of many oscillations summed in the form of a sinusoid, are the most common. A multi-frequency signal is thus a signal composed of the sum of many sinusoidal components, each of them characterized independently by three parameters: frequency, amplitude and phase. An example of a periodic signal is a special case but it can also happen that the signal does not contain any periodic signal, but only the sum of many sinusoids characterized of any frequency, generated by independent sources. This the most generally defined signal is of interest to this project, including also special cases, e.g. periodic signals.

The need to determine parameters of sinusoidal components of a multi-frequency signal is present in many fields of technology – in the processing of audio signals (acoustic, speech processing), radars and sonar (meteorology, oceanography), electricity (determine the power quality), mechanical vibrations (mechanics, seismology), biomedicine, optics (image processing), RF (radio astronomy), etc. For obvious reasons, it is also necessary to assume that the useful multi-frequency signal can be deteriorated (by noise) as it is applied in practice. The signal processing is performed by using the digital processing after the signal sampling in the system with the analog-to-digital (A/D) converter.

There are several methods of determining (estimating) parameters of oscillation components (i.e. parameters of sinusoids: frequency, amplitude and phase). One of them is spectral method using the Fourier transform (usually using the Fast Fourier Transform), which must be often supplemented by additional processing of the determined spectrum to obtain a desired estimation accuracy in many applications. One of the most important method groups of the additional processing in the frequency domain are the spectral interpolation methods.

Therefore, the DFT spectral interpolation understood in this way is a further processing of the spectrum (calculated most frequently using one of the FFT algorithms) and usually in the oscillation component analysis it takes into account a small number of the DFT spectral samples (relative to the entire spectrum). First described in the literature interpolation formulas (1970) significantly improved results of the parameter estimation of oscillation components assuming no interference of adjacent components (long-range leakage) at the expense of relatively low calculations. This combined with the use of the FFT algorithm made the whole process quick, though less accurate than other estimation methods (in the time domain or in the frequency domain). Over time, spectral interpolation methods became more accurate taking into account the spectral leakage from the other oscillation components, but at the expense of more complex formulas and thus an increased number of necessary calculations. This natural trend (greater accuracy at the expense of more computation) is compensated by a significant increase in computing capabilities of modern digital signal processing tools, such as digital signal processors or computer techniques in general. The most intense development of spectral interpolation methods is the period of the last decade. The most important limitation is still lower the accuracy and resolution (with high-speed estimation) with respect to the specific methods that require much longer calculation time (many orders of magnitude).

The goal of this project is to develop new spectral interpolation methods significantly improving the accuracy (by several orders of magnitude) at the significantly higher resolution (up to a level corresponding to the measurement duration of an estimated period fraction of a sinusoidal component). This is a significantly new element in the presented new research trend in the last decade. The basis here is the author's methodology, which gave great results in previous studies. Results obtained in the project are going to be examined by theoretical and simulation works and the experimental verification is going to be carried out using an application in the system of energy production based on renewable energy (photovoltaic panels). Such system, coupled with the power grid, has very high requirements to the estimation accuracy of grid signal parameters in a very short time (several - a dozen milliseconds). At the same time a low cost of implementation is desired, which requires the use of the most efficient (and very accurate) algorithms. Spectral interpolation methods are the best for such applications, but the key is to significantly increase their accuracy and resolution, which is the main goal of this project.