Power Spectral Densities (PSD) calculated with the Fast Fourier Transform (FFT)

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In the world of science and engineering, the Fourier transform is a foundation tool of the frequency domain. Because of the ‘fast’ algorithm invented by Cooley and Tukey, the FFT has become a very important numerical tool. Historically, many of its users have failed to require that Parseval’s (or Rayleigh’s energy) theorem be satisfied by the spectral density function they generate from the FFT. Consequently, a frequency domain estimate of a system’s total power using their result can be afflicted with huge errors. The simplest case with which to properly specify PSD units is that of an electrical system. Although the units found universally in the literature for that case are W/Hz, a more rigorous specification would be W/mho/Hz. The greater complexity of mechanical systems has been further cause for a widespread use of units having serious deficiencies. In place as a ‘standard’ for roughly three decades, it is responsible for great confusion. Although the set is usually labeled with the word ‘power’; its units of m²/s³/Hz is equivalent to watts per kilogram per Hertz per second. As such, it cannot represent power that is actually physical. The popularity of this density function is remarkable, given the near-universal practice of checking for errors through dimensional analysis. Having an extra unit of time makes it inconsistent with power in watts, so it should be more properly labeled acceleration spectral density (ASD). It differs by a frequency scaling factor from the ‘specific’ PSD, whose units are W/kg/Hz; but a correction can be readily applied to the ASD and thus transform it into a properly configured PSD. By means of quantitative examples using Excel spreadsheets, these important concepts will be demonstrated during the course of this presentation.

*For a rigorous tutorial treatment of this subject, type “spectral density calculations” into your favorite search engine.

Biographical Information

Dr. Peters received his PhD from the University of Tennessee in 1968 and spent the last 14 years of his career at Mercer University in Macon, Georgia, where he was Chairman of the Physics Department for more than a decade. Prior to joining the College of Liberal Arts faculty at Mercer, most of his career was spent as a faculty member at institutions of higher learning (Ole Miss, Texas Tech, and The U.S. Military Academy at West Point). While living in the Dallas-Ft Worth area before moving to Lubbock, he was involved nine years in the aerospace industry, first as part of the modernization of the Bell Air Cobra AH-1 attack helicopter. Some of the tools he employed while there became an important part of his follow-on physics work, such as using a Kalman filter to improve period estimates of a pendulum. After the Bell Helicopter stint, he joined LTV as part of President Reagan's Strategic Defense Initiative (SDI) 'Star Wars' program, where he created the infra-red thermal signature algorithms used during target acquisition phase by Vought’s air launched miniature vehicle that destroyed satellite P78-1 on Friday the 13th of September, 1985. While at Mercer, Peters focused on a plethora of mechanical oscillator types, with attention given to chaotic and complex behavior, some of which is detailed at http://physics.mercer.edu/hpage/peters.html. Whereas in the mid 1980's, SDI for him meant 'strategic defense initiative', the acronym came to be known in his later research to stand for 'Sensitive Dependence on Initial' conditions. This type SDI became well known in recent years because of the 'butterfly effect', a concept popularized by meteorologist and pioneer of deterministic chaos, Edward N. Lorenz. Some of the most significant accomplishments by Peters include a pair of articles that he authored for the 10th edition of McGraw Hill's Encyclopedia of Science and Technology. His article that is located in the encyclopedia's chaos section is accompanied by another article that was written by none other than world famous Lorenz (now deceased). The other Peters article, titled 'Anharmonic Oscillator', allowed him to introduce to the world a new concept (damping anharmonicity) as the result of his decades-long research on long period, low energy properties of mechanical oscillators. The other form of anharmonicity described in that article has been commonly known for centuries. Research that is described at the above referenced Mercer web page was motivated largely by three patents awarded to Peters, dealing with fully differential capacitive sensors; which are the basis for several laboratory instruments marketed by Tel-Atomic.
Inc. of Jackson, MI. His latest career activities have been increasingly of interdisciplinary type, involving (i) seismology, that resulted in his creation of a state-of-the-art digital seismograph called the VolksMeter (http://psn.quake.net/volksmeter/State-of-the-art_Digital_Seismograph.pdf) and (ii) frequency domain analyses that are part of a $381,000 ongoing NIH grant that was awarded to Mercer's Medical School to study the diagnostic capabilities of 'seismocardiography' in assessing heart abnormalities. One of the papers that grew out of this latest work is readily accessible for a complete reading by typing 'cardiac signals' into the Google search engine. Since retiring from Mercer, Peters has been working with a talented electronics engineering specialist to develop some user friendly products that work with his patented sensors. Some compact prototype instruments have already been created. Powered completely through a USB cable to the computer, they operate with Analog Devices' award winning capacitive to digital (24 bit MEMS) converter chip (the AD7745). These instruments are described at our webpage http://symcde.com.