A simplified approach with FFT and smartphone in high school physics

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Abstract. This communication explores the application of Fast Fourier Transform (FFT) utilizing smartphones and Jupyter Notebooks to introduce students to the amplitude spectrum as a graphical representation. Through targeted activities, students engage with real-world applications, analyzing sound signals and exploring sound properties in an accessible manner. We introduce our methodology and the materials created for this educational initiative. Additionally, we examine the feasibility and effectiveness of our intervention based on feedback from questionnaires administered to students and outcomes of a test specifically designed according to our learning goals.

Introduction to the module

In this communication we present our research into the feasibility of using real-time amplitude spectrum plot by Fast Fourier Transform (FFT) [1] in a classroom environment. The utility of the Fourier Transform spans engineering, physics, computer science and mathematics, facilitating the spectral analysis of various periodic functions. The advent of the FFT has significantly increased the efficiency of computing, and recent technological advances have made its application more widely available through devices such as microcontrollers and smartphones equipped with applications such as Phyphox and Physics Toolbox, and sensor-equipped devices such as iOLab and PASCO. These tools, complemented by programming libraries in languages such as Python and Matlab, allow students to be directly introduced to the FFT and provide valuable insights into periodic phenomena through graphical representations.
The main idea is that students can study waves in both the frequency and the time domain in real time to obtain complementary information relevant to the proper modelling of many physical phenomena. The FFT plot therefore can be viewed as an additional representation [2].
The physics education literature provides ample evidence for the use of FFT in various domains, notably in mechanics for data analysis and interpretation [3-6].
In this context, we developed two hands-on activites: analyzing light signals from a Michelson interferometer with speaker-induced disturbances, and examining AC current frequencies, highlighting the significance of anti-aliasing [7].

Module structure and pedagogy

The module, proposed for 12th grade classrooms, is organised into three lessons, starting with an introduction to FFT using real-world examples such as Shazam, followed by basic exercises in a Jupyter notebook on Google Colab to familiarise students with the FFT amplitude spectrum and its use. Students learned to identify the frequencies of an unknown signal, utilizing pre-built Python code for FFT analysis within an interactive Jupyter notebook, even in the presence of added noise—this mirrors typical experimental data conditions. Subsequent activities involve using the Phyphox app for analyzing sounds, deepening understanding of sound through experiments like Dual-Tone Multi-Frequency (DTMF) signaling [8]. The final lesson focuses on estimating the speed of sound using a straw and a smartphone's microphone, employing Phyphox for spectrogram analysis (see Table 1).

Table 1: The sequences of activities

Sessions	Activities
1st	Introduction to FFT with Jupyter Notebook in Python; sound analysis and spectrogram basics with Phyphox.
2nd	Experimental activity with Dual-Tone Multi-Frequency (DTMF) signaling; understanding the relationship between pitch and length in wind instruments.
3rd	Hands-on experiment to estimate the speed of sound using a straw and a smartphone, applying and reinforcing theoretical concepts in a practical setting.

Before the start of the module, a pre-questionnaire was administered to assess students' attitudes and habits towards the physics experiments and sensor devices. At the end of the module, a post-questionnaire was used to assess students' appreciation of the activities. Throughout the sessions, students worked collaboratively on Jupyter notebooks and experiments. A final test was designed to assess the achievement of learning goals. This assessment, although limited in scope, provided valuable insights into student learning. The assessment metrics focused on 'conceptual knowledge' and 'technical skills'. A rubric was used to assess performance in these categories, providing a detailed overview of student performance in relation to the main module objectives.

Conclusions

After implementing our module in two classes, the analysis of students' feedback from pre- and post-activity questionnaires underscores their appreciation for the educational value of the activities. Despite the brief nature of the interventions, observations across nearly all classes revealed that students effectively utilized the FFT amplitude spectrum. The assessment of the learning goals, based on the final test and group work, is also positive. In conclusion, our analysis suggests that this approach is feasible and can enrich students' understanding of certain physics topics.

References

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