Tidal and Current Parameter Extraction in Offshore Acuiculture Cages using an Ultra-Low Power Inertial Embedded System

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Abstract— **In this article, different algorithms for the extraction of wave and tide parameters are evaluated based on an ultra-low consumption embedded system. This system is oriented to determine the marine currents at different depths from inertial measurements. The microsystem is an inertial instrument which is used for structural and environmental monitoring by deploying at several depths of the mooring lines of offshore aquaculture cages. installation, to obtain raw acceleration data during data campaigns of more than 150 days. The raw data have been processed, applying signal processing techniques to obtain the tidal and wave parameters.**

Keywords-component; aquaculture,signal-proccesing, tidal-current meter.

I. INTRODUCTION

As demand, has grown, the aquaculture industry has innovated, applying countless techniques and methodologies in order to increase production and reduce costs[1]. The phenotype of the species of interest, for this industry, has been optimized to have a good base of reproducers that meet a set of characteristics in great demand. The reproductive cycle and the exploitation of these breeding individuals currently marks the viability of many species due to their long cycle of reproductive maturity. In the case of offshore facilities or also known as offshore, the waves and marine currents play a very important factor on animal welfare.

Even understanding the solidity of the state of the art in fluid mechanics and the exact knowledge of tidal forces, as well as the world movement of oceanic water, all the studies, up to the present, are mere models in which various authors culminate their study with the specification of the need to locally measure the parameters of said models to reduce their error. All the models proposed are framed within the so-called macro-models, which are particularized to the peculiarities of the specific places to be studied.

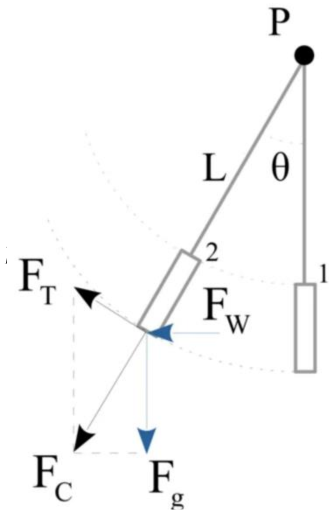

Figure 1. Inertial conceptual schema.

In this work, we introduce a novel instrument for acquiring tidal and current information for long-term measurements -data acquisition period of more than 150 days. The instrument has been tested in 2021 and 2022, for monitoring structural parameters of aquaculture cages in real-life operating conditions. The obtained data series has been post-processed for demonstrating that the instrument provide accurate tidal and current information. In addition, we introduce a FIR filter for reducing the signal information and a high-level algorithm in fixed point arithmetic for substituting the FFT.

The paper is organized as follows. Section II illustrates the theory behind the instrument. In Section III, the instrument for obtaining the inertial measurements is introduced. Section IV is devoted experimental measurements and FFT analysis. Section V introduces the Peak-Valley detector for frequency analysis. Finally, Section VI provides the conclusions and future works.

II. FUNDAMENTAL THEORY

In this work, we have studied the behavior model of the inertial measurement device (see Fig. 1). This is based on the principle of tilt and drag for the measurement of the forces involved on it. Since the device is in the water and specifically in the sea, a series of forces that act on it must be considered. These forces are the force of buoyancy and gravitation. The latter implies that the tides seek gravitational balance by moving and exerting a force on the device with a determined period.

In position 2 of Fig. 1, that is outside of equilibrium (position 1), the equation is as follows: $F_T+F_C=F_W+F_g$, where F_T and F_C are the tangential and centripetal forces, respectively, F_W is the water force and Fg is the gravitational force. Of course, when in equilibrium, F_C is the gravitational force F_g and, F_W and F_T are null. The movement of the tides due to the force of gravity is periodic, as we have seen, every 12,417 hours. In addition, the behavior of ocean currents is not the same on the surface as in deep water.

III. THE INSTRUMENT

Figure *2* illustrates the block diagram of the instrument. The embedded system is composed of a single-core microcontroller and a three-axis digital accelerometer. The system is managed by the ultra-low power microcontroller. In our case, it is the MKL17Z256 from NXP. This integrated circuit includes an ARM Cortex M0+ core with a maximum speed of 48 MHz, a flash memory for programs and data of 256 kB and 32 kB of RAM memory.

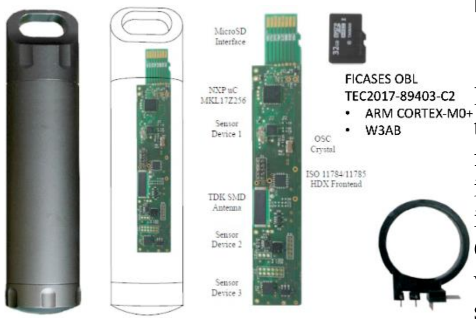

Figure 2. Block diagram of the instrument.

The microcontroller is directly connected, through its I2C and SPI ports, to an accelerometer and a digital memory (uSD). The NXP MMA 8451Q device is used as a digital accelerometer, see **¡Error! No se encuentra el origen de la referencia.**. It has three axes with 14/8 bit as inertial measurement element. On the other hand, it is essential to include an energy accumulator to allow the unit of measurement (UM) to work autonomously. The total cost of the measure unit is less than $50. Included in this cost is a printed circuit board and batteries.

IV. Technologichal Deployment

The ideal place for the deployment of infrastructures related to the practice of aquaculture is a marine space protected from strong tides and wind, such as bays or, failing that, beaches. However, these areas are already occupied by other industries such as port infrastructure or tourism. The quick and easy solution is to locate the new facilities between 1km and 3km from the coast. In general, this range of distance provides a location where shallow water currents are not dependent on the seafloor or the shape of the shoreline. In other words, most of the turbulence that appears on the coast is not present. Also, in most cases this range of distances is considered open sea.

The instrument was deployed in the infraestructure of Aquanaria S.L, at Castillo del Romeral, Gran Canaria, Spain. The chosen deployment is located on the continental shelf. Several instruments were placed in a depth range up to 35m. The complete system was fully operative for long-term measurements for 189 days (27 weeks).

V. Data Series: Experimental Measurements

The data acquired in a long-term campaign, under real-life operating conditions, by several units of MUs in an offshore cage in operation have been studied to determine the frequencies of the dominant components of oceanic tides in the high seas, in the short (10 minutes), medium (1 day) and long term (one week).

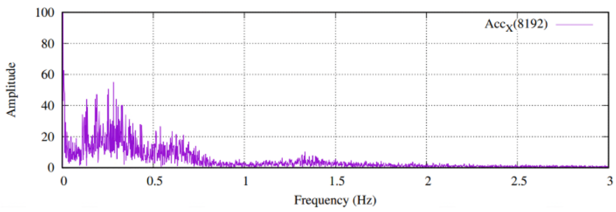

Figure 3. FFT Analysis for 8192 samples at the X acceleration axis.

In the analysis carried out, the problem of defining the time window to be analyzed is addressed. As an example, Figure 3 illustrates the FFT analysis for a window of 8192 samples. The samples are form the X axis of the accelerometer. At the range of frequencies from 0,25 Hz to 1,3 Hz, we find AM modulated accelerations. By decreasing the sampling window, this effect is more evident. Figure 4 illustrates the FFT analysis for 128 samples, where the resolution is reduced.

Therefore, the physical effects to be observed in the behavior of the tides have very different frequencies. The translation of these data from the time domain to the frequency domain has made visible the problem of extracting fundamental frequencies surrounded by lobes equivalent to an amplitude modulation.

Because we use FFT analysis, the limited computational effort capabilities of the employed UM prototype introduce resource allocation as a design variable to determine the algorithm to extract the fundamental frequencies of ocean tides in marine areas.

The selected sampling frequency of 12.5 sps has been shown to allow the measurement of faster local tidal currents, as well as

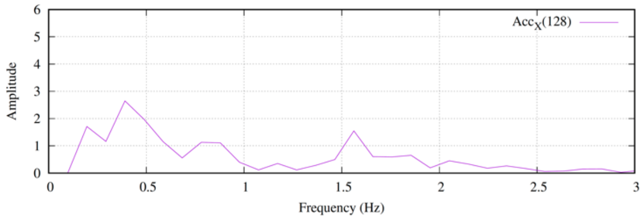

Figure 4. FFT Analysis for 128 samples at the X acceleration axis.

those due to gravitational forces. The fastest ones are below 3 Hz and the slowest around 23 mHz. The range of frequencies to be measured requires different techniques to be efficient in terms of memory and CPU effort since it is a low consumption application.

VI. Frequency Analysis by Peak-Valley Detector

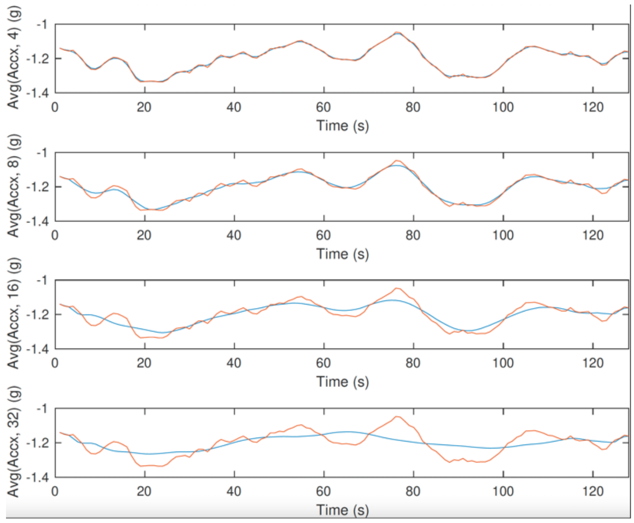

Figure 5 Temporal representation for the FIR filter response of 4, 8, 16 and 32 sampling window, at 12,5 sps.

Figure 5 illustrates the FIR filter response for different sampling windows of 4, 8, 16 and 32 samples. The input signal is sampled at 12.5 sps. The higher the number of samples of the window the lower cutoff frequency for the low-pass filtering. By subtracting the response between two of them, the frequencies of the pass-band filter are computed. The time lapse between two zeroes of the resulting signal is the half of the signal period.

VII. Conclusions

This work has found that the use of the FFT could be useful as a first approximation step to determine the range of the main frequencies close to Hz. Once this range is obtained, it is better to use a peak-valley detector in instead of the FFT due to the variability of the incoming signals. In all the experiments, our prototype has demonstrated the usefulness of the proposed method to obtain the acceleration profile of ocean tides in the high seas.

Acknowledgment

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References

[1] J. Sosa, and J.-A. Montiel-Nelson, "Novel Deep-Water Tidal Meter for Offshore Aquaculture Infrastructures," *Sensors*, vol. 22, no. 15, pp. 5513, 2022.