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MULTIBEAM IMAGING OF THE ENVIRONMENT AROUND MARINE RENEWABLE ENERGY DEVICES

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1 INTRODUCTION

The drive towards sustainable energy has seen rapid development of marine renewable energy (MRE) devices (e.g. [1]), and current efforts are focusing on wave and tidal structures. However, little is known of the general effects of installing and operating these devices. Impacts on the surrounding ecosystems have been assessed differently, from benign to adverse (e.g. [2, 3]). The experience gained over the years, and around the world, has been summarised in recent reviews, which all highlight the need for more generic modes of assessment (e.g. [4-6]). Workshops involving MRE developers and regulators have also emphasized the need for an improved understanding of the baseline environment, (e.g. [7]), stressing that, as each technology is different and greatly influenced by the site location, it is necessary to look at common impacts and easily adaptable technologies. Starting in September 2011, the NERC/DEFRA collaboration FLOWBEC-4D (*Flow, Water column and Benthic ECology 4-D*) is investigating these effects at test sites in Orkney (European Marine Energy Centre: EMEC) and Cornwall (Wave Hub), combining the data from bird observations, shore-based marine X-band radar surveys of wave and current data, detailed modeling of the flow and water column, passive acoustic monitoring and the development of a remote-sensing sonar platform. These studies will look at the impacts of MRE devices on fish and sea birds, as well as the surrounding environments. They will also look at potential impacts when individual devices are scaled up to large arrays.

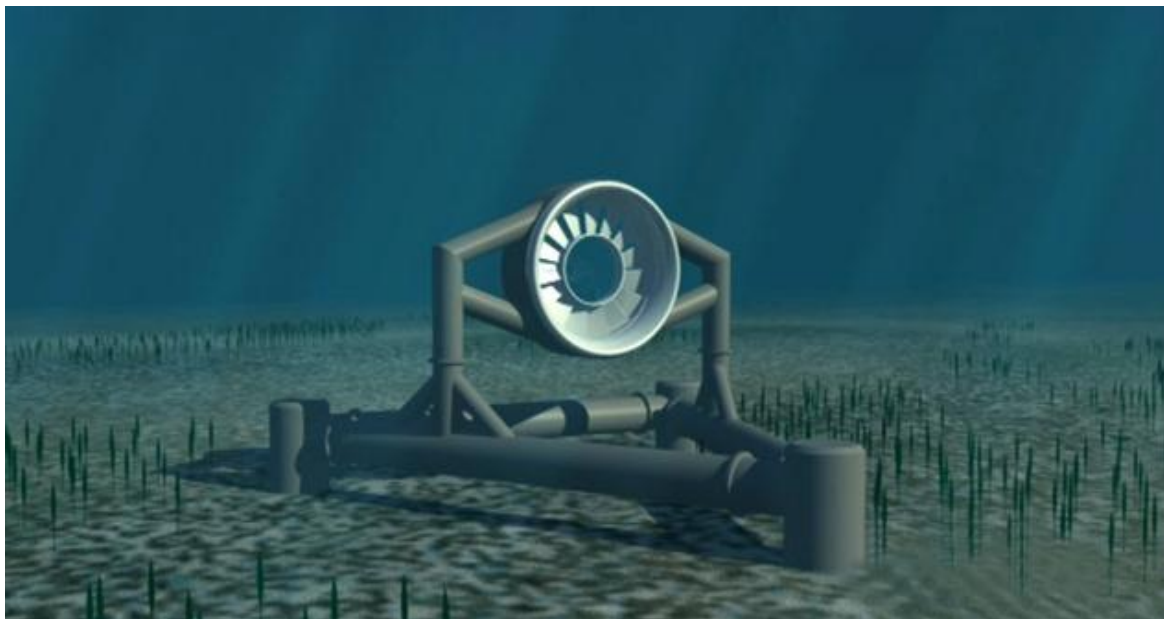


Figure 1. Conceptual view of a typical MRE device, in this case a turbine similar to the one in the first test area at the European Marine Energy Centre (EMEC). Image credit: OpenHydro Group Ltd., <http://www.openhydro.com/images.html>.

Acoustic tools are the best adapted to assess the hydrodynamic habitat preference of various functional ecological groups (benthos, plankton, fish, birds and marine mammals), and how individual species may use preferred flow conditions. Figure 1 shows one of the devices planned for deployment at the EMEC test site in Orkney. This tidal turbine will use the local strong flows (greater than 8.5 knots) and will be deployed in water 40-50 m deep. Wave Hub deployments, planned for later in the project, will investigate another test site related to wave energy converters. Both sites experience challenging conditions, with short deployment times and very dynamic environments. Several series of measurements will be collected over 2012 and 2013, using a moored multibeam echosounder (MBES) and a multi-frequency echosounder to provide fine-scale vertical information and both qualitative and quantitative (velocities, species, behavior) in a continuous time-frame over envisaged deployment periods of 2 weeks each time. The following sections will describe the University of Bath's contribution to this imaging platform.

2 MULTIBEAM IMAGING OF DYNAMIC ENVIRONMENTS

Multibeam echosounders provide the advantage of a wide cover, a calibrated response and the provision of both range/bearing and scattering strength information for any target either on the seabed or in the water column. They have been used with great advantage for the mapping of marine habitats (e.g. [8, 9]). "Traditional" mapping uses a moving platform and the multibeam sonar images the seabed, and sometimes the water column, below the survey vessel. However, for monitoring the environment around MRE devices, the multibeam sonar will be fixed to a frame on the seabed, imaging the water column, any moving acoustic targets and changes in the seabed around fixed structures like MRE devices (if within the field of view).

The Imagenex 837 Delta T multibeam sonar has been selected for its low cost, its ease of use (direct ping scheduling and access to raw measurements), its low power consumption and previous experience in other challenging environments (e.g. [10-12]). Working at 260 kHz, the Imagenex sonar images a wide swath of 120° by 20°, with 120, 240 or 480 beams and at rates of up to 20 pings/second. Its operating range varies from 0.5 to 100 m and can be adapted in real-time during operation. This sonar measures the backscattering strengths (in dB) of all targets, relative to a source level of 190 dB re. 1 μ Pa @ 1 m (Patterson, pers. comm., 2012). Pulse lengths vary with the range setting (e.g. 0.3 μ s at 50 m range). The range setting will also affect the resolution of targets, nominally expected to be 0.2% of the range. This would correspond to 4 cm along the line of sight at 20 m range, and resolutions of 0.2 – 0.5 m across-swath. As such, it is perfectly adapted to map behavior and habitat preferences of fish, birds and mammals. Figure 2 shows typical raw measurements in Arctic waters. This screen-shot shows an average of 5 pings, with a sloping seabed below a thin layer of macrophytes mostly visible in the center beams (e.g. [10, 11]). The water column shows other targets, mainly a shoal of small fish, 0.4 by 0.5 m, around 10 m above the seabed, and smaller targets closer to the seabed, assumed to be individual fish from their sizes (60 cm across-swath and 10-20 cm thick). Other applications with the same sonar have looked at mapping dense plankton concentrations (Megill, pers. comm., 2010) and even thermal layers (Imagenex Technology Corp. case study). As long as they remain within the wide field of view of the imaging sonar (120° by 20°), all of these targets can be tracked and measured using standard image processing tools.

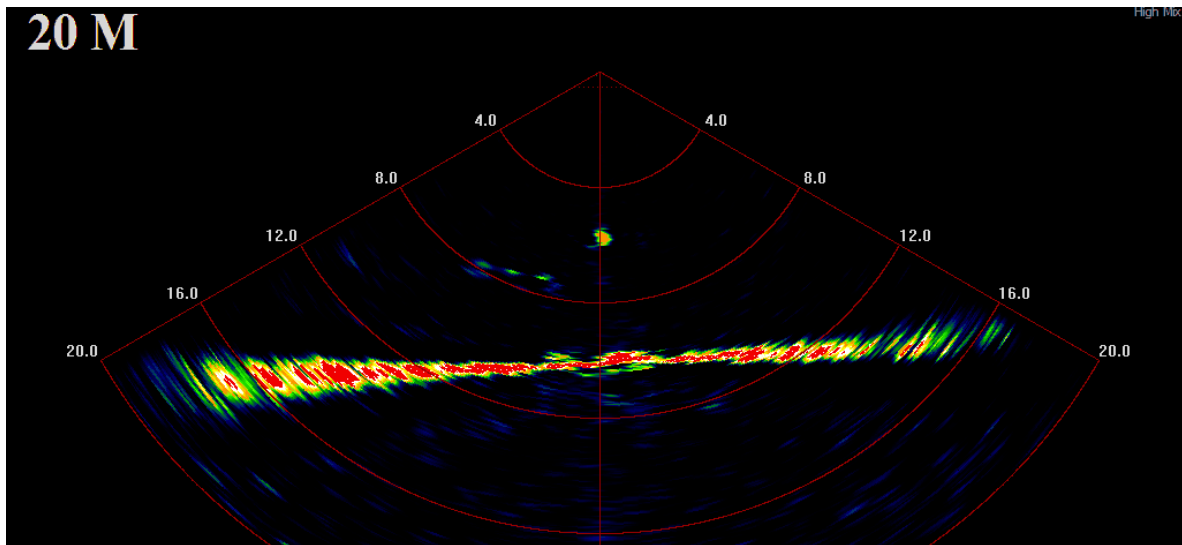


Figure 2. The Imagenex 837 Delta T multibeam sonar can detect small targets within the water column. These raw measurements show a sloping seabed, with a shoal of small fish in the center beams (40 cm vertically by 53 cm horizontally) and a series of smaller targets on the left (bearings 14.9, 24.3 and 31.9°). From their sizes, 0.3 to 0.6 m across-swath and 10-20 cm thick, these are assumed to be individual, larger fish.

3 IMAGING AROUND MRE DEVICES

3.1 Acoustic Setup and Imaging Platform

The platform for multibeam imaging is intended to be deployed relatively close to the MRE device of interest, whether at EMEC (tidal turbines) or at Wave Hub (wave energy converters) with the MRE device within the field of view of the MBES. The platform consists of the Imagenex 837 Delta T multibeam sonar, used in combination with a Simrad EK60 multi-frequency sounder (Figure 3). Both sonars will be aligned in the direction of the tidal flow. The Imagenex sonar will point vertically upwards and be tilted to cover part or most of the MRE device within its acoustic field of view, enabling clear imaging of the interaction of marine life with the device and within its wake. Because of its wide imaging angle, the MBES will detect targets with a high, centimetric resolution along the tidal flow (which most animals will follow anyway, because of behavioral preferences and also because of the strength of this flow), but with limited resolution across the flow. Field tests will reveal whether variations in the scattering strength as animals move across the flow can be detected with enough accuracy.

Carrying on along the axis of the tidal flow, potential targets will then be within the field of view of the Simrad EK60 multifrequency sounder, operated by Marine Scotland Science and the University of Aberdeen. Its 38 kHz echosounder has a 12° conical beam, whereas the other echosounders (120 and 200 kHz) have 7° conical beams. Comparison of scattering strengths at the different frequencies enable identification of the types of fish swimming, and this sounder has also been used successfully to look at diving sea birds (e.g. [13]). The two sonars will be integrated on the same platform and communicate throughout the data acquisition period. Each deployment is intended to last for at least two weeks, taking continuous measurements at rates of several pings per second. This induces engineering challenges for on-board processing and storage of the multibeam measurements, adaptation of the duty cycling to the power available as the deployment progresses, and generally to the extremely dynamic flow environment (potential presence of debris impacting the frame, risk of tipping or tilting in strong flows).

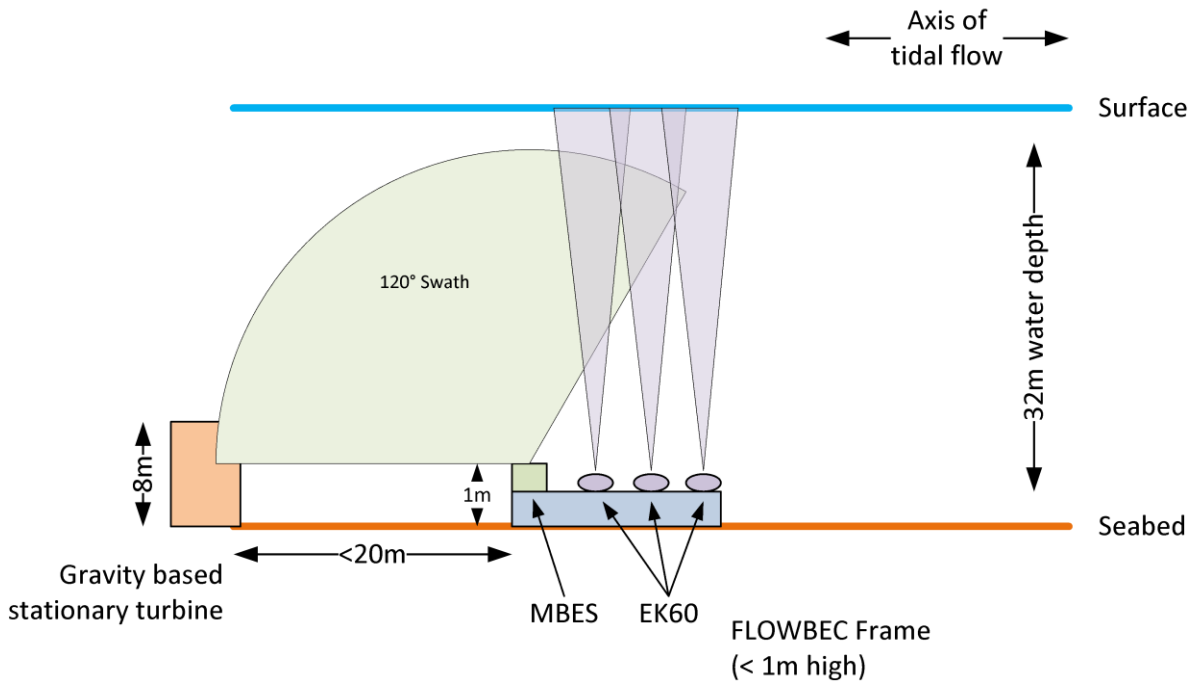


Figure 3. Setup of the FLOWBEC acoustic imaging platform. The Imagenex Multi-Beam Echo-Sounder (MBES) images part of the MRE device and the water column along the axis of the tidal flow. It is supplemented with a Simrad EK60 multifrequency sounder, enabling identification of the types of fish. Actual deployment depths will vary with the local setting.

3.2 Multibeam Control System

Figure 4 below shows an overview of the multibeam control system, including the interface to the EK60 multifrequency echosounder. To ensure reliability, each system has a separate power supply and controller, and for flexibility, is housed in separate pressure vessels.

Power is supplied to the multibeam system by a bank of five 220-Ah sealed lead acid batteries connected in parallel and housed in stainless steel housings mounted on the base of the frame. These batteries can be recharged *in situ* using high-current connectors and vent plugs to allow a 24 hour service period between deployments. A similar (larger) battery bank supplies the EK60 system. The batteries are suitably rated for the overall power consumption for a 2 week deployment, with a safety factor for later expansion and appropriate temperature de-ratings. A low-voltage cutout protects the batteries against deep-discharge and the voltage and current are continually monitored by the controller. A fused distribution panel supplies DC-DC converters which provide the various voltages required throughout.

A VIA ARTiGO A1100 x86 computer with a 120-GB solid-state disk controls operation of the multibeam and records all data. This controller was selected for its small form factor, very low power consumption and flexibility of development. The accompanying EK60 is configured to transmit at a rate of 1 ping per second and a synchronizing pulse is transmitted to the multibeam control computer and read by a National Instruments USB-6008 data acquisition board. Custom NI LabVIEW code is used to read this pulse and interface with a specially compiled version of the Imagenex 837 Delta T control software. A series of 8 multibeam pings spaced at 90-ms intervals are scheduled in the remaining fraction of a second before control is returned to the EK60. This ping scheduling avoids any acoustic interference between the two devices.

The inclination of the mounting frame is continually logged throughout deployment to ensure the frame has not moved in the high currents. The clocks are regularly synchronized between the two controllers to allow the data from the two sonar devices and inclination sensor to be registered in post processing. The inclination sensor can also be read during deployment using a through-water acoustic communications link to verify positioning of the frame before it is released.

Aside from the TTL ping synchronization line, inter-device communication is performed using Ethernet and all components are selected for their low power consumption. Data download and diagnostics are possible without opening the pressure vessel, using either a wired Ethernet connection or a Wi-Fi connection to each controller.

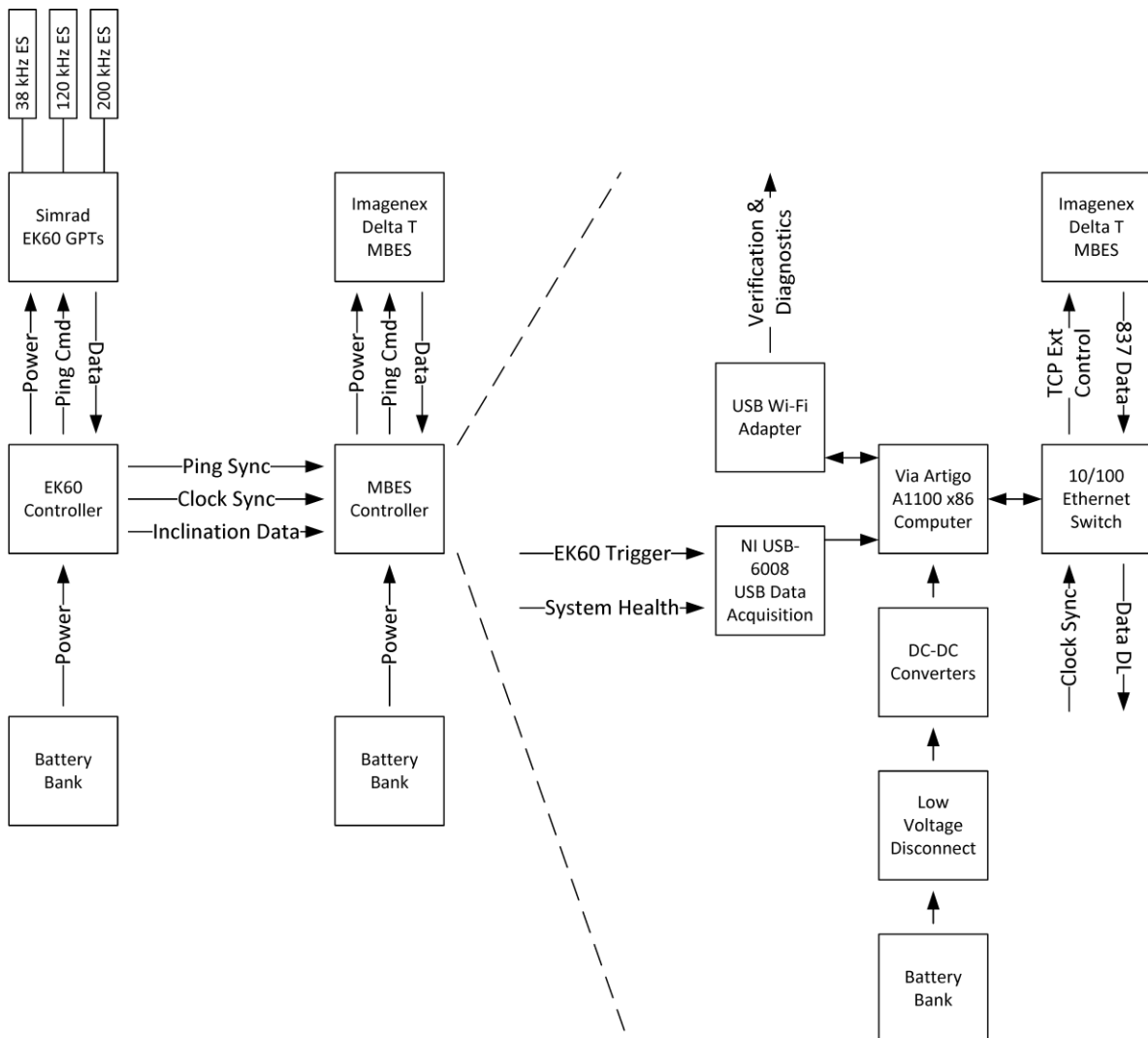


Figure 4. The systems layout of the Simrad EK60 and Imagenex 837 Delta T multibeam control electronics, including the interfaces between the two systems to ensure data synchronisation and to prevent acoustic interference.

3.3 First Deployment

The first deployment site will be at the European Marine Energy Centre (EMEC) in Orkney. Funded by the European Union, EMEC is using the strong tides around Orkney to host the world's largest

testbed for renewable energy devices. As such, it is an ideal proving ground for the technologies designed to monitor these devices. This is planned for May-July 2012, with the first underwater tests of the system already underway. The entire frame, supporting the Simrad EK60, Imagenex 837 Delta T and associated controllers, batteries and inclination sensor are self-contained and intended to be deployed for 2 weeks at a time with short turnaround times between deployments. Deployment times are limited to the order of 20 minutes, dictated by the short period of slack water at neap tides. Results and first images will be published on the FLOWBEC website (<http://noc.ac.uk/project/flowbec>) as soon as possible after the first deployments.

4 CONCLUSIONS

Increasing commitments to renewable energy in short timescales have seen a rush toward marine renewable energy sources and devices. Little is known of the general effects of installing and operating MRE devices, at all depths and in all environments. The NERC/DEFRA project FLOWBEC aims to address the challenge of monitoring a significant portion of the volume around MRE device(s), using above-the-water sensors like radar, and below-the-water instruments like sonars. The Imagenex 837 Delta T has been chosen for its low cost, ease of operation and versatility. It has been integrated into a subsea platform to be first deployed in May-July 2012 at a tidal test site in Orkney, at the European Marine Energy Centre.

With a working frequency of 260 kHz, the Imagenex 837 Delta T can provide high resolution range and backscatter information on a variety of targets around the MRE device and in the water column. These targets can be detected and tracked through the axis of the tidal flow using standard image processing techniques. The combined use of the Simrad EK60 multifrequency sounder, operated by Marine Scotland Science, will enable identification of particular fish species. Fish, marine mammals and diving seabirds can all be followed in the course of their interaction with MRE devices, above water and below water. This information will be of direct use to marine ecologists and ecosystem modelers.

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