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CHALLENGES TO INTEGRATING ACTIVE ACOUSTIC SENSORS

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INTRODUCTION

Before large-scale implementation of marine renewable energy can move forward, it is necessary to understand the environmental impacts of these devices to ensure that the benefits of marine energy outweigh the environmental costs [1]. Environmental monitoring around pilot scale installations can help to close the knowledge gaps surrounding the environmental effects of marine energy devices [2]. Instrumentation to perform this research must provide data about environmental interactions that may occur frequently with low consequence (e.g. a marine mammal reacting to underwater noise) as well as interactions that may occur infrequently with high consequence (e.g. a marine mammal collision with a device). Additionally, this instrumentation must be able to perform reliably over extended periods in harsh environments [3].

THE ADAPTABLE MONITORING PACKAGE

The Adaptable Monitoring Package (AMP) is an integrated instrumentation package that supports a suite of instruments that provide comprehensive information about the environment around a marine energy device [4]. The AMP uses a “plug and socket” architecture consisting of the instrument package and a specially designed docking station. The AMP is deployed and “plugged in” to the docking station by an inspection class ROV

TABLE 1. PROTOTYPE AMP INSTRUMENTATION PAYLOAD

Instrument (operating freq.)	Effective Range	Relative Resolution	Data Bandwidth	Potential Challenges
icListen digital hydrophone array (0-250 kHz)	> 100 m (omnidirectional)	Low/Moderate[1]	5 MB/s	• Masking noise produced by active acoustic instruments
BlueView acoustic camera (900/2250 kHz)	< 10 m (45° x 20° field of view)	Moderate	10 MB/s	• Animal behavior disturbance from sound • “Crosstalk”
Kongsberg M3 multibeam sonar (500 kHz)	< 100 m (120° x 3-30° field of view)	Moderate	10 MB/s	• Animal behavior disturbance from sound • “Crosstalk”
Nortek Signature acoustic Doppler current profiler (1000 kHz)	< 30 m	Moderate	0.01 MB/s	• Animal behavior disturbance from sound • “Crosstalk”
Stereo-Optical Camera	< 10 m (45° x 45° field of view)	High	80 MB/s	• Animal behavior disturbance from artificial light

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[1] A single icListen hydrophone is capable of detecting marine animal vocalization, while multiple hydrophones may allow for source localization.

augmented by an auxiliary tool skid. The AMP combines active acoustics, passive acoustics, and optical cameras to provide a comprehensive picture of the environment around a marine energy converter. Table 1 summarizes the cabled instruments in the AMP prototype. Continuous data acquisition by these instruments over multi-month periods would lead to vast (petabyte) amounts of data (i.e., "data mortgages"). To combat this problem, instrumentation can be integrated to inspect incoming data in real-time and trigger data acquisition only during a period of interest. Instruments capable of real-time target detection (e.g. passive acoustics or sonar) will trigger data recording from other instruments using a series of circular buffers (e.g., 30-60 s). For example, if the BlueView acoustic camera detects a fish, it will trigger a buffer offload from all instruments. This triggering method reduces the amount of archival data that does not contain useful information.

When multiple active acoustic instruments are operating simultaneously, the transceivers may receive an acoustic signal emitted by a different instrument. This phenomenon, referred to as "crosstalk", can corrupt portions of the data. In addition, there is a risk that the stimulus (sound or light) from the instruments could disrupt normal animal behavior. These challenges are summarized in Table 1.

METHODOLOGY

Initial integrated instrumentation testing was conducted to investigate two aspects of the potential challenges: active acoustic crosstalk and the potential masking of passive acoustic detection of marine mammal vocalizations by the active acoustic instruments. Preliminary steps towards automated target detection and cooperative target testing were also performed.

The Kongsberg M3 multibeam sonar (M3), BlueView acoustic camera (BlueView), and Nortek Signature acoustic Doppler current profiler (ADCP) were secured adjacently on a test rig that aligned the swaths of the BlueView and M3. The test rig was mounted to the hydraulic ram of the R/V Henderson, an Applied Physics Laboratory research vessel outfitted for calibration and testing of underwater acoustic instrumentation. Figure 1 shows the instrument arrangement. The hydraulic ram allowed the instrument rig to be lowered to mid-water (approximately 2 m below the surface) and rotated through a complete circle.

TABLE 2. ACOUSTIC CROSSTALK TEST (GREY CELLS DENOTE ACTIVE INSTRUMENT COMBINATIONS)

	M3 EIQ	M3 Im.	BV	ADCP	BV & ADCP
M3 EIQ	▨	▨			
M3 Im.	▨	▨			
BV			▨		▨
ADCP				▨	▨

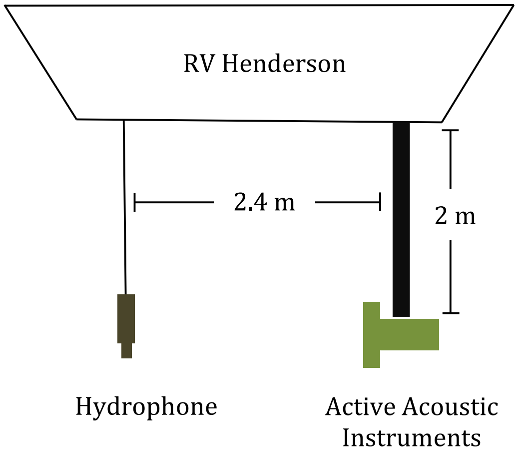

FIGURE 1: CROSSTALK TEST INSTRUMENT CONFIGURATION

To evaluate crosstalk between the active acoustic instruments, data from each instrument was recorded while the other instruments were cycled on and off (Table 2). The M3 multibeam sonar has two operating modes: the standard imaging mode (Im.), and an enhanced image quality mode (EIQ) which uses separate transducers and combines a number of consecutive pings to provide a higher quality image, but a slower update rate, shorter range and potentially less-accurate tracking of rapidly moving targets. For the purpose of this test, these two modes were considered separately.

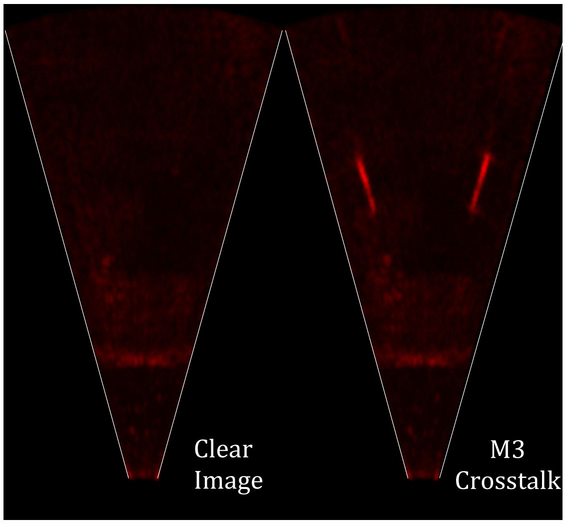

FIGURE 2: CROSSTALK ON BLUEVIEW ACOUSTIC CAMERA (REGIONS OF HIGH INTENSITY SIGNAL PARALLEL TO FIELD OF VIEW)

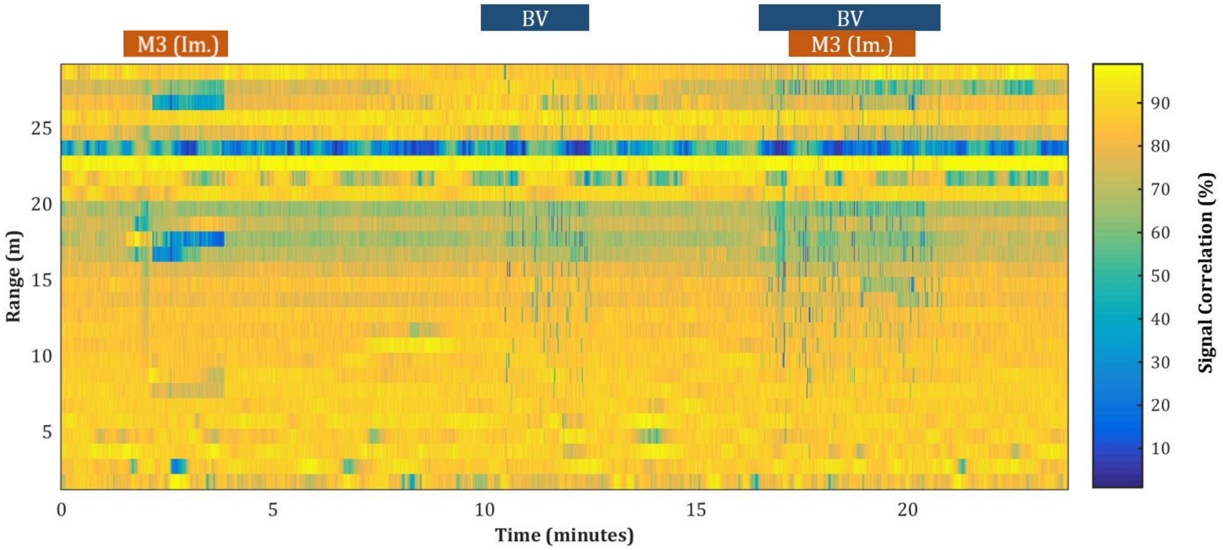

FIGURE 3: ADCP INTERFERENCE FROM M3 AND BLUEVIEW WITH INSTRUMENT OPERATION PERIODS INDICATED.

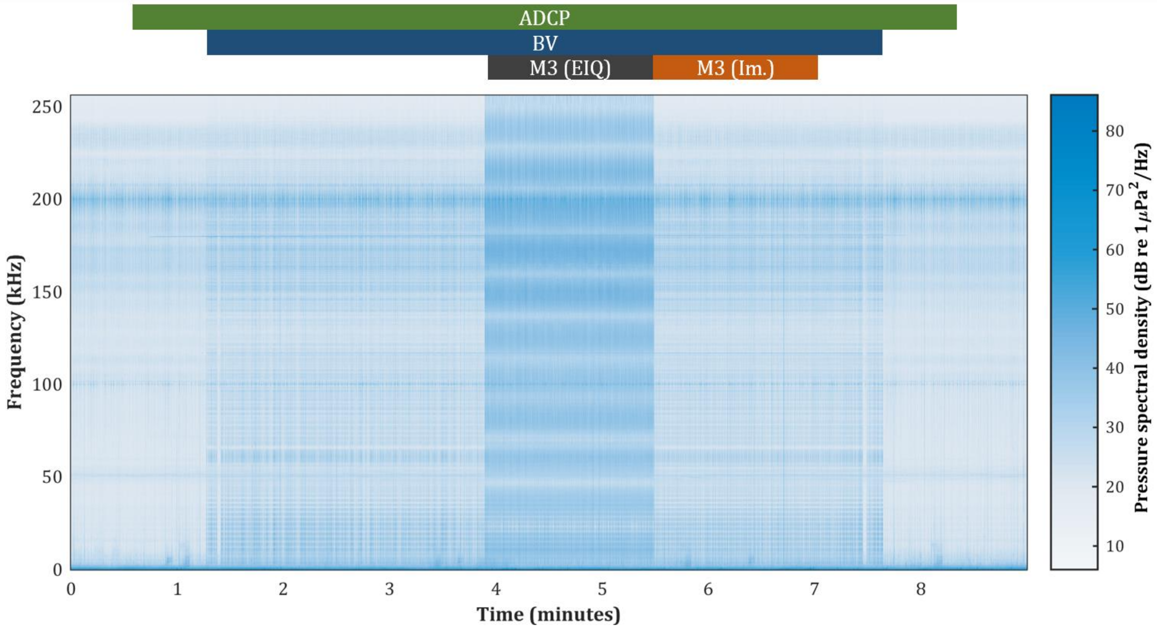

FIGURE 4: PASSIVE ACOUSTIC DETECTION OF ACTIVE ACOUSTIC INSTRUMENTS. INSTRUMENT OPERATION PERIODS INDICATED BY COLORED BOXES. UNASSOCIATED 200 KHZ TONE PERSISTENT FOR ALL TESTS.

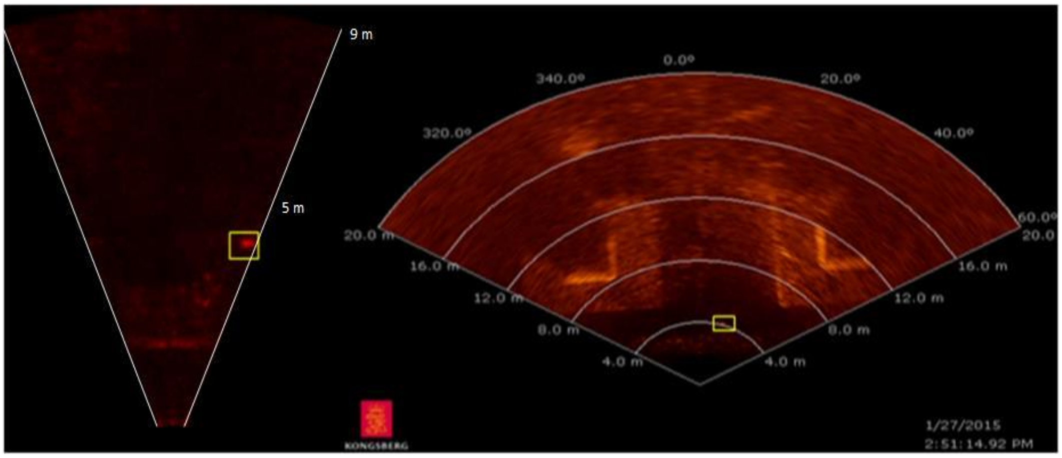

FIGURE 5: COMMON TARGET ACQUISITION (CALIBRATION SPHERE, YELLOW BOX) BY BLUEVIEW AND M3 SONARS.

To establish that the instruments are capable of target detection and handoff, synchronized detection of a target (3.8 cm tungsten carbide acoustic calibration sphere) present in both the BlueView and M3 swaths was collected while moving the target left-to-right and up-and-down through the swath. To monitor for active acoustic noise at frequencies of interest for marine mammal vocalizations, the icListen digital hydrophone was deployed at a distance of approximately 2.4 m from the active sonars at an equivalent depth. This placed the hydrophone beyond the acoustic near-field [5] for all three sensors. Passive acoustic data were collected at 512 kHz sampling rate with the active sonars oriented directly at the hydrophone (i.e., worst case scenario) and post-processed to acoustic spectra with a bandwidth of 0.125 kHz.

RESULTS

Initial testing of the AMP instruments showed that efforts to mitigate acoustic crosstalk will be necessary and that some active acoustic instruments produce significant sound at frequencies well below their primary operating frequency.

Active Acoustic Crosstalk

Active acoustic crosstalk was present on all instruments. Figure 2 shows an example of crosstalk between the BlueView and M3. The pattern and intensity of the crosstalk depended on the relative ping timing of the instruments. Similarly, significant crosstalk was observed from both the ADCP and the BlueView camera on the M3 image. Figure 3 shows signal correlation data from one beam of the ADCP, annotated with information about BlueView and M3 operation. There is obvious degradation in signal correlation, leading to erroneous velocity (not shown). The crosstalk from the BlueView appears to degrade performance at all ranges, though the crosstalk from the M3 is more distinct. Again, the pattern and intensity of the crosstalk depended on the relative ping timing of the instruments, which was not regulated by a central clock during these experiments.

Passive Acoustic Interference

Figure 4 shows passive acoustic spectra recorded during the crosstalk test. Neither the M3 (Im.) nor ADCP appear to generate substantial sound at f < 250 kHz. However, the BlueView produces broadband sound down to f < 10 kHz, as does the M3 (EIQ). The pressure spectral density from the M3 (EIQ) at the observed frequencies is 20-30 dB higher than the BlueView.

Target Testing

Figure 5 shows the same target detected by both the BlueView and M3 sonar. This suggests that target hand-off between the active sonars should be possible and will be used to develop filtering, target detection, and tracking algorithms. These same algorithms will be used in “cooperative target tests” (e.g., ROV, drifter) to benchmark algorithm performance.

CONCLUSIONS

These preliminary integrated instrumentation tests provide two pieces of valuable information. First, because the crosstalk present in the active acoustic instruments is not part of the image background (and, therefore, not easy to subtract from the image), it could cause false triggers or target interference. The final system architecture will need to include ping scheduling between the instruments to minimize this interference. Second, while active sonars do not require light to function, the sound produced by some instruments occurs at the same frequency as some marine mammal vocalizations. This may mask the detection of marine mammal vocalizations, or be detectable by marine mammals, which could cause behavioral changes. The difference in transmission pulse frequencies between operation modes for the M3 is particularly notable. Further testing will quantify the source level, frequency content and directionality of each active acoustic instrument, which will provide more information to contextualize this sound relative to marine mammal hearing and ambient noise.

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