PRELIMINARY TARGET MEASUREMENTS FROM A PROTOTYPE MULTISPECTRAL SYNTHETIC APERTURE SONAR

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Abstract: The AquaPix Multispectral Synthetic Aperture Sonar (SAS) is a next-generation seafloor imaging product in development by Kraken Robotic Systems Inc. It will operate in multiple bands widely spaced over a wide acoustic spectrum, enabling acoustic spectroscopy, buried object detection, and enhanced target classification. This paper presents early results from opportunistic target measurements carried out during development and testing. Various multispectral data products are presented from an aluminium pipe target suspended in the water column in a controlled lake experiment. The data products include circular SAS images from multiple spectral bands, a multispectral image fusion, and an acoustic colour signature. The multispectral imagery is shown to simultaneously expose the acoustic features of the target corresponding to its geometric shape and its elastic response. These early results demonstrate the feasibility and potential of the system, which is expected to provide a powerful new capability in seafloor mapping.

Keywords: *Synthetic aperture sonar, multispectral, target scattering*

1. INTRODUCTION

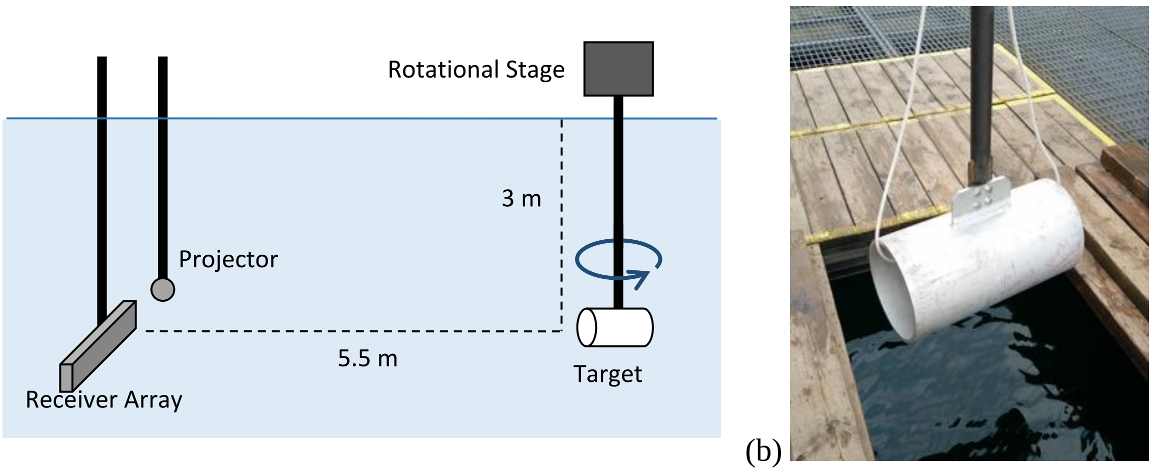
The AquaPix Multispectral SAS will operate in multiple spectral bands from approximately 2-5 kHz in the audible region up to 200 kHz in the ultrasonic region [1]. SAS images from the high-frequency bands will provide the high resolution and high contrast already offered by conventional SAS [2]. The other bands will provide an enhanced capability to characterise the seafloor via acoustic spectroscopy (as in satellite and airborne electromagnetic multispectral systems [3]). Moreover, the low frequency bands will penetrate beneath the seafloor to enable detection of buried objects and inside objects to excite resonant modes specific to internal structures and composition.

Opportunistic target measurements have been made using a basic prototype of the AquaPix Multispectral SAS during early development and testing. A simple aluminium pipe target was selected with a 12-inch outer diameter, 24 inch length, and 0.5-inch wall thickness; this resembles an aluminum pipe target deployed in related US studies [4,5].

2. EXPERIMENTAL METHOD

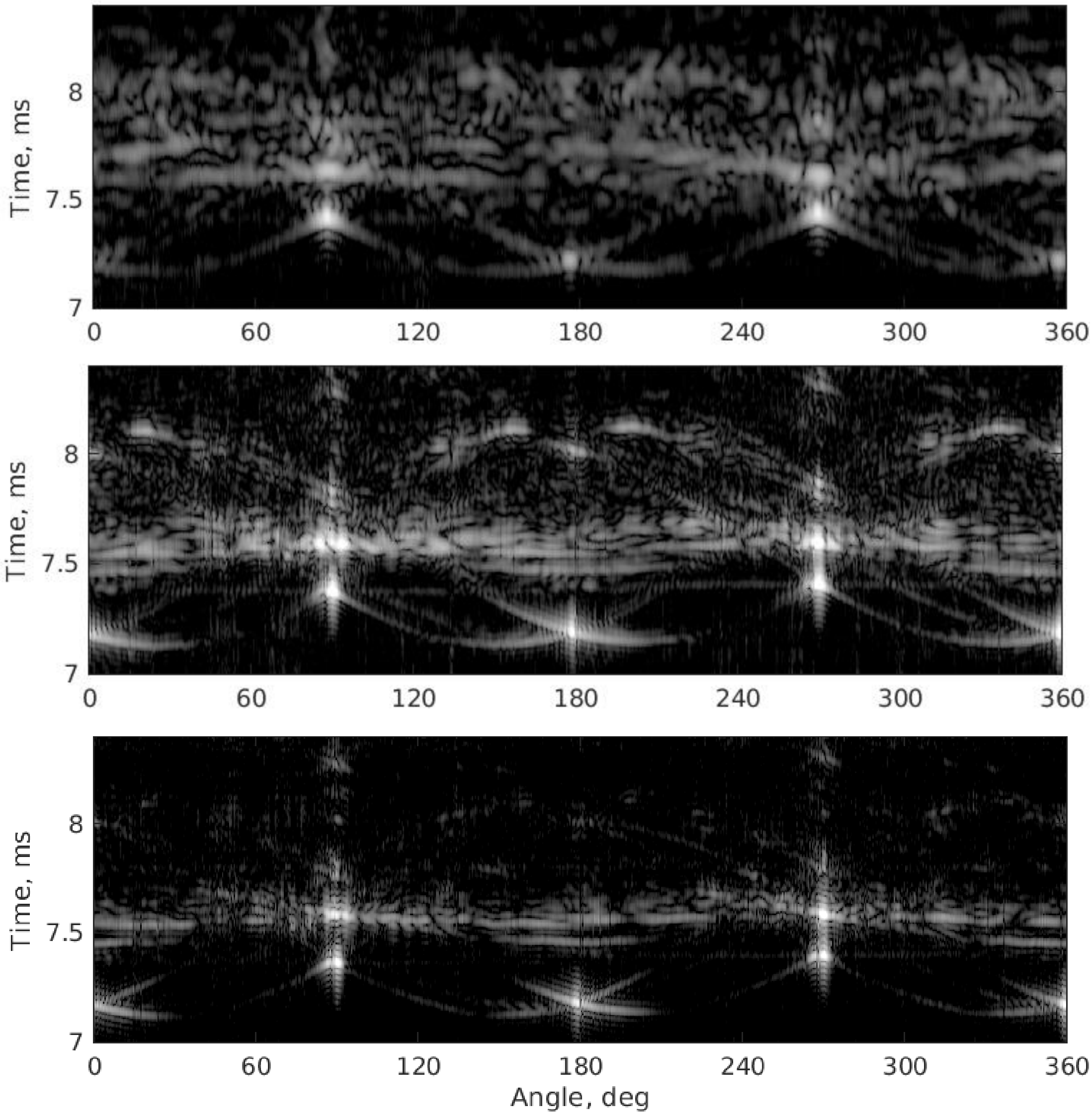
The experiment was carried out from a pontoon in the Kelk Lake underwater testing facility in the UK. Ideally, the measurements would have been made in the free field. However, for simplicity, the target was bolted to a pole via a welded flange and suspended from the rotational stage on the pontoon. (In a dedicated experiment, more effort would have been made to minimise the influence of the mounting structure.). Two projectors covering the bandwidth from 15 kHz to 120 kHz and the wideband receiver array were suspended from poles at a distance of 5.5 m from the target. The target was suspended at a depth of 3 m and the water depth was approximately 9 m. An illustration of the experimental geometry and a photograph of the aluminium pipe target is shown in Fig. 1.

The target was rotated through 360 deg and wideband acoustic scattering measurements were made at increments of 0.25 deg. Repeated "baseline" measurements were then made without the target but with the pole and flange only. The purpose of these measurements was to determine the influence of the mounting structure and other reverberation for baseline subtraction.



(a) (b)

Fig. 1: Experimental setup*: (a) measurement geometry; (b) aluminium pipe target suspended from the rotational stage.*



(a)

(b)

(c)

Fig. 2: Multispectral circular SAS data *from the aluminium pipe target and mounting structure over a 40 dB dynamic range: (a) 15-40 kHz; (b) 40-80 kHz; and (c) 80-120 kHz. (Baseline data and baseline subtraction are not shown.)*

3. PRELIIMINARY RESULTS

The raw echo data is shown in Fig. 2 for three spectral bands: 15-40 kHz, 40-80 kHz, and 80-120 kHz. These bands were selected for convenience due to the opportunistic nature of the experiment and we have chosen to denote them as “low”, “medium”, and “high”-frequency (LF, MF, and HF). The raw data have been processed into various useful data products: 1) circular SAS images from each band, 2) a false-colour image fusion from all three bands, and 3) the acoustic colour signature from all bands.

The circular SAS images from each band are shown in Fig. 3(a-i). The baseline subtraction was reasonably effective at removing the influence of the mounting structure. The images from the different bands were observed to exhibit different characteristics. The HF band shows the basic geometrical structure whereas the MF and LF bands contain non-geometric features that we attribute to elastic scattering. In the MF band, strong features can be observed in the internal corners of the target image. In the LF band, what appears to be resonant “ringing” can be observed behind the geometrical features However, further analysis is required to properly explain these observations.

A false-colour image fusion was created by encoding the three spectral bands into three RGB colour channels: LF – red, MF – green, and HF – blue. This is shown in the bottom row of Fig. 3(j-l). It presents a more compact and intuitive representation of the multispectral imagery. The popular acoustic colour representation [6,7] is also provided in Fig. 4, showing the angle and frequency dependent scattering characteristics of the target.

4. SUMMARY

Preliminary results from the AquaPix Multispectral SAS prototype have been presented. These provide an early indication of the types of data product that will be generated by this new product. Multispectral image fusion conveys literal *acoustic colour* information by encoding it together with the high resolution SAS images into a single RGB image. The aluminium pipe test target was shown to exhibit different acoustic characteristics in the different spectral bands and this highlights the added value of multispectral SAS for enhanced target classification.

5. ACKNOWLEDGEMENTS

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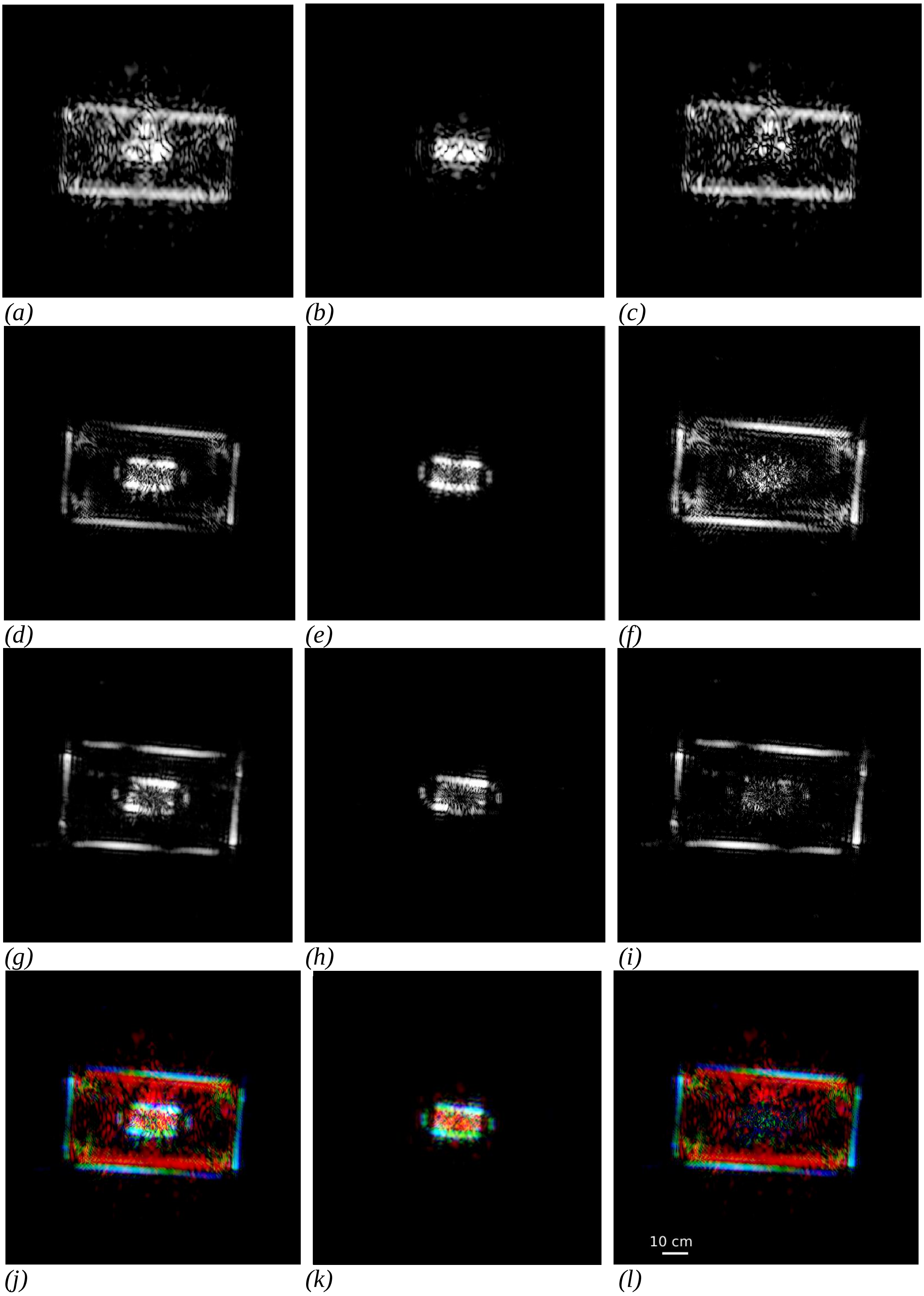

Fig. 3: Multispectral circular SAS images *of the aluminium pipe target over a 10 dB dynamic range: (a,b,c) 15-40 kHz; (d,e,f) 40-80 kHz; (g,h,i) 80-120 kHz; (j,k,l) multi-band fusion with the images from the three bands encoded in red, green, and blue channels respectively; (left column) target and mounting structure; (middle column) baseline with mounting structure only; (right column) target after baseline subtraction.*

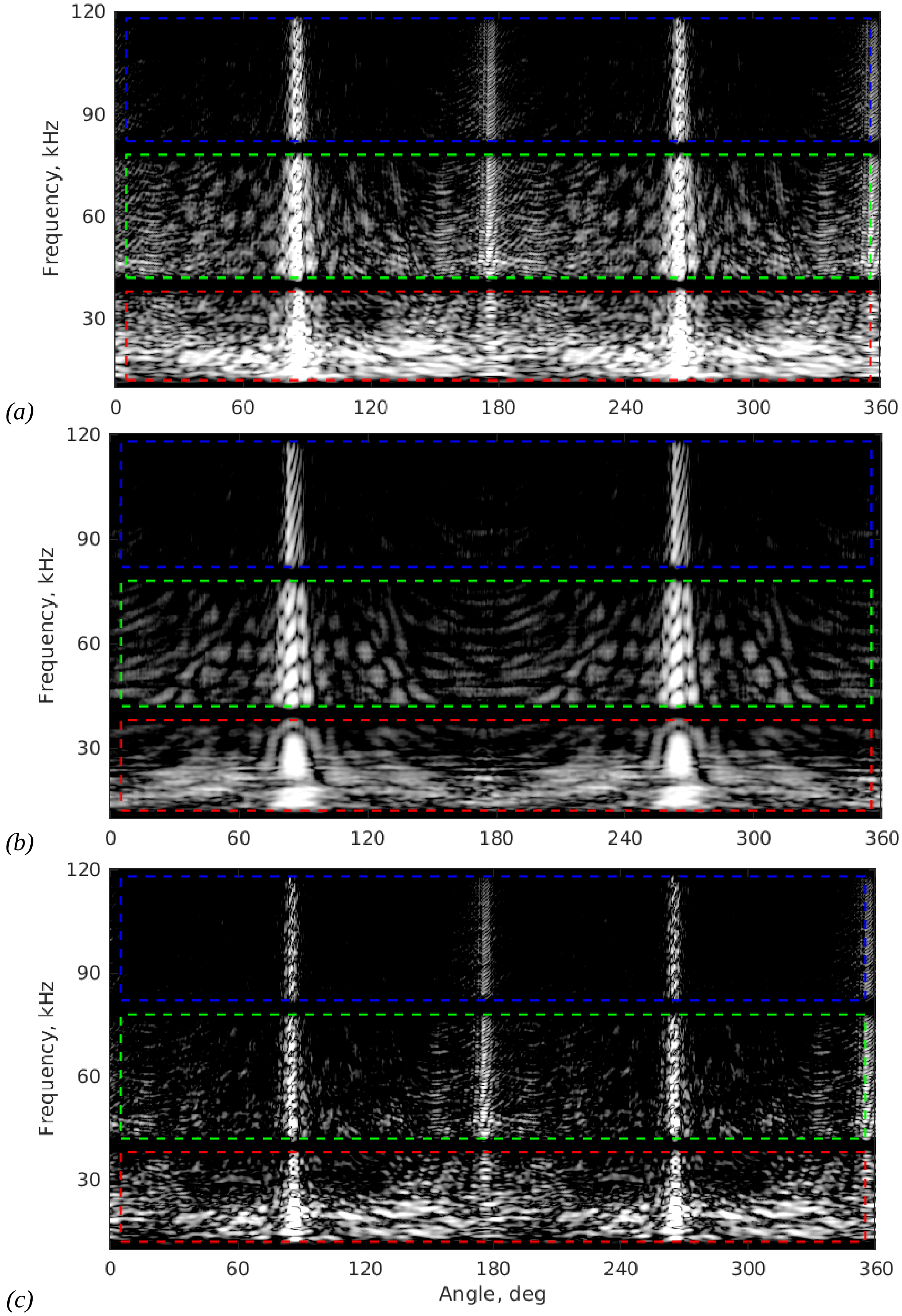

***Fig. 4: Acoustic colour signature** of the aluminium pipe target over a 10 dB dynamic range: (a) target and mounting structure; (b) baseline with mounting structure only; and (c) target after baseline subtraction. The red, green, and blue boxes indicate the three spectral regions selected for multispectral image fusion.*