USING SMART HYDROPHONES IN AMBIENT NOISE MONITORING

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1 INTRODUCTION

Underwater passive acoustic monitoring equipment has evolved from simple hydrophone sensing elements to include integrated amplification and digitization. With the addition of local signal processing and data storage a new instrument has evolved: the Smart Hydrophone. The features of this new class of instrument are discussed in the context of ambient noise monitoring.

Recent legislation to protect and preserve the marine environment, such as the Marine Strategy Framework Directive in Europe (Directive 2008/56/EC) outlines the Good Environmental Status. Descriptor 11 covers Introduction of energy, including underwater noise, which must be monitored to protect the marine environment.

Research institutes around the world have started building ocean observatories, that excel at collecting a broad range of information on the environmental status in the areas near observatories, and are developing standards for data interchange. Instruments that allow direct integration and comparison of data from different sources are needed.

Uses of this instrument include the self-calibrated hydrophone, acoustic data logger, portable spectrum analyzer, and acoustic event detector.

2 BACKGROUND

2.1 Ocean Ambient Sounds

Ocean ambient sounds are produced by human activity, sea life activity or natural earth events, such as wind, rain and earthquakes. Observers of ocean ambient sounds are interested in knowing the sound level, frequency content, and in many cases, the source of the sounds recorded. Noise pollution observers are trying to detect and quantify anthropogenic sounds.

Marine ambient noise observers require ocean sensor data that can be delivered in the shortest time, is of high quality, and follows standards.

2.2 Key Elements

Advances in technology mean that larger data sets can be stored on solid-state memories. However as bandwidth (or sample rates) increase, the limiting factor is the effective throughput of the data channel. At this point, alternatives in acquiring the data may be needed.

The key elements of the Smart Hydrophone are

1. **Integrated**
   Combining the sensor, analog and digital electronics and calibration information into a single unit simplifies the process of acquiring accurate data. Eliminating cables and connectors in the analog domain gives the designers more control over signal quality; improving noise performance, gain accuracy and linearity.

2. **Provide calibrated data**
   Waveform data stored or reported by the instrument should contain calibration information, allowing the data processor to convert readings to uPa, or suitable physical units. This still allows the data processor to apply frequency dependent corrections if they are required.

   Stored data should contain sensor information at the start of each file. If the instrument setup changes, such that the calibration is affected, a new file is created with the correct settings. The calibration of the instrument is stored in the instrument's memory, and is used in all data produced by the instrument. The calibration data should be accessible by the operator.

3. **Stream real-time waveform data**
   When the hydrophone is permanently connected, such as a wired observatory, waveform data can be streamed. For higher bandwidth data this is normally done via a network connection.

   Data should be clearly time-stamped to avoid issues with delays in networks, and to ensure instrument synchronization with other acoustic, and non-acoustic sensors. The data stream should be blocked and indexed so that the receiving station can ensure data is correctly interpreted, and accounts for any lost data blocks.

   The recommended approach is to provide a header block once per second that indicates the date and time to a one-second resolution. The first sample in the first block corresponds to the first sample in the one-second interval. The One Second Header contains information that describes the waveform, such as calibration and sample rate. It may also contain auxiliary information, such as temperature, instrument status, and instrument version.

   Streamed data need not include only waveform data, but may include processed data, such as spectral records or click counts. Each data type is assigned to a different network 'channel', to simplify the data collection process. The streaming format should follow standards to ensure data is accessible to all users.

4. **Store waveform data (or subsets of it)**
   Instruments not connected to a high-speed link will need to log waveform data.
   This should follow a standard file format, such as WAV, making it broadly accessible. This format allows the embedding of support data, such as instrument calibration, timestamp, temperature etc.
   High sample rates use more storage space that limit the total recording time. Instruments should be configurable such that storage can be 'duty cycled', storing some number of minutes out of each hour to reduce memory use.
   Memory use can be reduced in other ways, such as logging only when an acoustic event is detected.

5. **Can be synchronized using GPS or similar technique**
   The instrument should keep time, and store it in the data. With latencies in networks and data communication channels, the arrival time of waveform data cannot be relied upon to reflect the conversion time of data. The data messages containing waveform data must describe the time of samples explicitly.
   This is done by dividing the waveform messages into one second blocks, and starting each on a one-second boundary. Each one second block contains a timestamp with a resolution

of one second. The first sample in the waveform message is the first on taken after the most recent second transition.

The timebase accuracy is determined by what is required to resolve hydrophone arrays. For timing resolution of 1 msec the best-case positioning accuracy is 1.5 meters. It is possible to achieve 1 usec timing accuracy using GPS or similar Pulse Per Second technology. Assuming the clock is synchronized, this first sample should correspond with first samples recorded from other hydrophones, within the tolerance of the instrument's timebase. Instruments connected to a data collection system should be synchronizable using a GPS Pulse Per Second type signal, or a comparable Ethernet standard, such as IEE 1588, the Precision Timing Protocol. This ensures that acoustic data collected in different locations is synchronized, and multiple hydrophones treated as an array.

6. **Process data to provide averaged spectral data**
   In many cases for environmental monitoring, post-processing consists of transforming the data into a spectral format and averaging samples. Performing this in the instrument reduces data bandwidth by a huge margin, enabling the instrument to be used in places where waveform data cannot be continuously acquired. Examples of this are when tethered to a buoy with a data radio, or mounted on an ROV with a serial connection.

   Processing also allows low bandwidth processed data to be continuously stored alongside subsets of high bandwidth waveform data.

7. **Detects/counts acoustic events**
   Passive acoustic monitoring applications sometimes include event detection, for example sea mammal clicks, or calls. Event detection may also include detection of vessels or impulse events. Having the instrument report or store events adds significant value to the decision maker in timeliness, and in reducing the time spent processing long records searching for events. Logged data containing just event data is very efficient.

3 CONCLUSION

Hydrophone data is becoming an important tool for researchers who are listening in the ocean. Taking advantage of new signal processing capabilities, high density memory and precise timing, in small devices brings huge value to the digital hydrophone, making it useful for a broad range of ocean monitoring applications.

As standards evolve for data processing and presentation of acoustic data, smart hydrophones will be able to adapt to the changes, ensuring data consistent and comparable data. In the future smart hydrophones will be used for sound classification and detection.

4 REFERENCES

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