Choosing the Best Hydrophone Sample Rate

Sampling Sounds
Listening in the ocean requires hydrophones. Smart hydrophones present digital sound data to us by sampling the signals produced by sound waves. How we sample affects what we can do with our data. Poorly sampled data is difficult to improve. The signal bandwidth determines our sampling rate. How do sounds present outside this bandwidth affect our data? How do we deal with these signals?

How do we choose the right sample rate, and predict how much data we are collecting? Sampling at high rates ensures that a broadband range of signals is collected, but we risk collecting too much data. How do we find the right balance between getting the data we need while avoiding the problem of collecting too much?

Nyquist Rate
Time-varying analog signals must be sampled at least twice their maximum bandwidth, according to the Nyquist Sampling Theorem. We can sample no slower than twice the maximum bandwidth, but we are allowed to sample much faster.

A problem arises when sounds with frequencies higher than the maximum bandwidth are sampled. This ‘aliasing’ creates a form of undesirable interference. A good hydrophone system design puts filters before the converter to minimise out of band signals. This is difficult if the signals are near our bandwidth limit because filters are not perfect. They start to work gradually. Filters can also introduce phase distortion, lowering overall quality. Sharp filters that do not add phase distortion are difficult to design.

A simple way to solve the alias noise problem is to sample at a rate greater than the Nyquist rate. This provides a region where the quality of the data affected by the anti-alias filter is not important. This dead-band gives us a zone where the filter can start to work while having minimal effect on the measured signal.

This approach is used by sigma-delta converters where a very high sample rate is used and the data is digitally processed to lower a bandwidth. The higher sampling rate makes it easier to design the anti-alias filter.

For broadband signals the bandwidth is still less than one-half of the resulting sample rate. Changing high sample rate data to a lower sample rate is called decimation. Varying the decimation rate lets you vary the effective sample rate without needing to change the anti-alias filter.

Smart Hydrophone filters and amplifiers are designed to give very flat amplitude and phase response in the frequency band being sampled.
Choosing Sample Rates

In icListen the operator selects the bandwidth setting, and the best sample rate is determined by the software. To get best performance, the signal bandwidth is 40% of the sample rate.

It is tempting to make the bandwidth as high as possible, to ensure any detail is captured. The following table shows the amount of storage needed for a range of signal bandwidths. Notice that twenty days of 100kHz data gives us over 1 TByte of data.

<table>
<thead>
<tr>
<th>Bandwidth</th>
<th>Sample Rate</th>
<th>Gbytes / Day</th>
<th>Gbytes / Month</th>
</tr>
</thead>
<tbody>
<tr>
<td>1000 Hz</td>
<td>2.5 kS/sec</td>
<td>0.6</td>
<td>19</td>
</tr>
<tr>
<td>10,000 Hz</td>
<td>50kS/sec</td>
<td>6.4</td>
<td>192</td>
</tr>
<tr>
<td>25,000 Hz</td>
<td>62.5 kS/sec</td>
<td>16</td>
<td>486</td>
</tr>
<tr>
<td>100,000 Hz</td>
<td>250 kS/sec</td>
<td>64</td>
<td>1900</td>
</tr>
</tbody>
</table>

If the data is to be transmitted in real-time to a receiving station, then the throughput of the data channel must be known, to ensure it does not become the bottleneck in the collection process.

The chart below shows the probability of getting all data over four channel types, versus the signal bandwidth. Note that the loss of data is gradual as the data rate increases, so that if 90% of data is acceptable, then a higher bandwidth is possible. This shows that a satellite can stream 200 Hz waveform data with good success, while a GPRS cellular link can stream 2 kHz data. The Ethernet wired connection can carry the highest throughput, around 200 kHz.

A separate white paper covers ways to reduce data by processing it in the instrument.

A key part of project design is knowing how much data users can securely handle and process when setting bandwidths, and data needs.

You can learn more about Smart Hydrophones by visiting our website at InstrumentConcepts.com.