Acoustics – Digital, Spread Spectrum, DSP, Wideband…

What does this mean for Real World DP Operations?

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Introduction

Signal Processing Techniques

What does this mean for DP Operations?

- Noise
- Multipath
- Battery Life
- Interference
- Update Rate
- Repeatability

Gulf of Mexico Project Results

Conclusion
• Increasing use of acoustic position reference systems.

• Primary reference in many cases.

• Increase in number of DP vessels working in close proximity.

• Technology developments in other areas enabled new techniques to be applied to acoustics.
What Is Digital Signal Processing?

Digital Signal Processor  Convert to Analogue

Convert to Digital  Digital Signal Processor
Up until recently, DSP devices were very power hungry and unsuitable for cable-less offshore applications. Expansion of Cellular Telephone industry has led to development of low power DSP devices.
Signal Processing Techniques

![Graphs and Diagrams]
Acoustic Signal Types

**Tones**

- Single Frequency
- No modulation
- Frequencies must have sufficient separation to provide separate channels
Acoustic Signal Types

Wideband Signals

- Single carrier Frequency
- Phase modulation to write data onto signal
- Phase changes identify code
- Hundreds of codes can be generated
  - Not all are suitable for navigation due to cross correlation
- Known as Phase Shift Keying (PSK)
Wideband Signals (contd.)

- Number and position of phase changes identifies code or identity
- Signal represented by binary number in digital domain
Correlation Processing

- Replica of all signals stored in receiver
- Each incoming signal correlated against replica to find match.
- Correlation function samples incoming signal and compares with stored signals.
- When match is found, correlation filter peaks, at all other times, output from filter will be a low value.
Correlation Processing

Signal

Replica

Perfect Match

Response

Detection Threshold

Large Peak

Very Accurate Timing

Very Accurate Timing

Correlation Processing

Signal

Replica

Perfect Match

Response

Detection Threshold

Large Peak
Wideband Acoustic Signals
Correlation Processing

Replica

Signal

Very

Accurate Timing Detection

Threshold

Large Peak

Replica Signal
Correlation Processing

- Correlation filter output provides:
  - Precise confirmation of which signal has been received, as correlation spike will only occur with matching replica.
    - This allows many separate signals to be defined – 100s
  - Very precise time of arrival, at the point of the correlation spike.
    - This allows for very accurate range and multipath immunity even in very low signal to noise ratios
Wideband is used to describe the use of complex signals to determine range and position.

A wideband ranging pulse will have a bandwidth of several kHz. Channels will have overlapping carrier frequencies.

Spread Spectrum describes the communication aspect of a system where the bandwidth exceeds the number of bits of information transferred.

Spread Spectrum has recently been used as a generic term to describe systems utilizing complex signals.
Sound Velocity Profile

- SVP fundamentally limits the operating range of any Acoustic system
  - If there is no communication path you cannot communicate
  - Type of signal or modulation is irrelevant
- Lowering surface transducer below surface layer may overcome it
- Propagation effects can be modelled in advance if SVP is known
What Does This Mean For DP Operations?
Noise

- Noise is limiting factor in performance of analogue acoustic systems
- Sonar Equation:

\[ SNR = \text{Source Level} - \text{Transmission Loss} - \text{Noise} \]
• Reduce the effect of noise:
  - Increase transponder source level
  - Use beam steering to focus on transponder signal
  - Design nulls into receiver to minimize effect of noise
• Improvements with Wideband:
  - Ranging Precision 10 x greater than narrowband systems.
    • Significant advantages in Time of Arrival determination.
  - Improved bearing resolution.
    • Significant advantages in Phase determination with larger arrays.
  - Improvements in data telemetry.
    • More Robust in the presence of noise.
    • Improved data integrity (FEC).
    • Increased baud rates.

Note
• Detection.
  - Correlation of wideband signals does improve ability to resolve position and allows detection thresholds to be reduced.
    • Once detected, performance over analogue systems is greatly improved.
• Defining the Time of Arrival

**Tone in Noise**

- 8ms tone plus noise and no multipath

**Wideband in Noise**

- 8ms wideband plus noise and no multipath
The results above show the differences in time of arrival timing between wideband and tone signals, transmitting from a RovNav 5 and receiving on a USBL (Type 8021 or 8023). Even in poor SNR the time of arrival results from the wideband system compares favourably to EHF tone systems with a SD TOA of better than 30us (45mm).
### Tone – In Noise

- **Northings**: 5579729.68
- **Eastings**: 416770.62
- **Average Value**: 5.95 m
- **Std. Deviation**: 36.91 m
- **Spread**: 23.54 m

### Wideband – In Noise

<table>
<thead>
<tr>
<th>Position</th>
<th>Average Value (m)</th>
<th>Std. Deviation</th>
<th>Spread</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eastings</td>
<td>416771.02</td>
<td>0.06 m</td>
<td>0.43 m</td>
</tr>
<tr>
<td>Northing</td>
<td>5579730.14</td>
<td>0.08 m</td>
<td>0.59 m</td>
</tr>
</tbody>
</table>
Trial Noise Conditions – High Noise
Multipath
Multipath

- Multipath with either:
  - Result in a second received signal which will be longer than the direct path. This will be gated out through software.
  - If reflected path is not sufficiently different, incoming pulses will overlap and neither will be detected or validated. This will result in position dropout.
Effect of Multipath on Tone Signals

Destructive Interference

Constructive Interference
Effect of Multipath on Wideband Signal
Stronger Direct Path

Weaker Indirect Path

Shallow Water Trials Set Up
Compatt Hung 5m Down & Upside Down
Achievable multi-path resolution is 1 binit or 0.25ms
0.25ms = 0.37m
• Wideband signals allow better performance with lower Signal to Noise Ratios.

• This allows the user to reduce the source level of the transponder and extend battery life.
Interference

- Tone systems rely on frequency separation for channel identification. With simultaneous operations, care must be taken to ensure no channel clashes.
- Wideband signals allow for hundreds of unique channels, removing any concerns over frequency management.
Digital signals allow more techniques to increase true update rates for DP.

Example is ping stacking, where interrogations and replies are stacked in the water column. This allows DPO to maintain control over acoustics.
• Wideband signals offer a more precise measurement point as detailed above.

• ToA measurement in an analogue signal is more difficult, especially in noisy conditions.
• Wideband signals can be used to improve positional repeatability.
• Or they can be used to maintain current repeatability in environments where Signal to Noise ratios are reduced (high noise etc.).
Positioning Results:

USBL position

- CASIUS 1.8m 1Drms accuracy in 2000m of water (despite pole)
- Calibration important for acoustic performance, not only offsets.
- WB better than tone
- 2-3s update rate in 2000m of water
- Congested area - WB much better for acoustic inference

TMS positioning (secondary)
Telemetry:

Mini C5 on every acquisition unit connected via RS232 modem link

- Telemetry modem integrated into PHAROS 1.07 - data sent via acoustic link and exported to client system OR can be used by PHAROS if relevant data
- WB Telemetry links
  - 1500 bits/s (RPSK)
  - 10,000 bit/s link (HDRL)
- 1.3MB of QC data from 6 acquisition units transferred on project
- Telemetry collected to directional C5 over +/-45 degree cone of operation in 2000m of water
- Telemetry proved extremely reliable with 95% up time
ROV Equipment

USBL Transponder

ROVNav 5 Transducers
Calibration of Acquisition Unit Positions

New Technique – Array Box-in was used.

Data was acquired from West and East sail lines.

A traditional BaseLines and Box-in Calibration was also undertaken for comparison.
Array Boxin was used to position Compat5 units 101 – 106.

Vessel Steamed East Line & West Line while data was gathered.

Inter-array baselines were measured. Surface Box-in of 207 & 208 was also performed.

Purpose of 207 & 208 was for USBL calibration purposes. These units also used to make absolute calibration of array by conventional means.
### Results (contd.)

<table>
<thead>
<tr>
<th>Array Box-in Only</th>
<th>Array Box-in (All)</th>
<th>Array + Baseline (2)</th>
<th>Array Box-in + Baseline Combined All</th>
<th>USBL (Average fix)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Node Box-in Only</strong></td>
<td>2607228.67</td>
<td>2608315.00</td>
<td>2607747.00</td>
<td>2608878.51</td>
</tr>
<tr>
<td><strong>Node Box-in (All)</strong></td>
<td>223.88</td>
<td>551.35</td>
<td>307.50</td>
<td>189.66</td>
</tr>
<tr>
<td><strong>Array + Baseline (2)</strong></td>
<td>227.86</td>
<td>551.95</td>
<td>314.90</td>
<td>193.25</td>
</tr>
<tr>
<td><strong>Array Box-in + Baseline Combined All</strong></td>
<td>0.81</td>
<td>0.82</td>
<td>0.10</td>
<td>-0.81</td>
</tr>
<tr>
<td><strong>USBL (Average fix)</strong></td>
<td>2607212.2</td>
<td>9921553.67</td>
<td>2608296.51</td>
<td>9919196.85</td>
</tr>
</tbody>
</table>

### Key Elements:

Comparison between conventional calibration (box-in & baselines) and array box-in using Wideband Replies to USBL transceiver:

**East Line**

Mean $\Delta E = 0.34m$ Mean $\Delta N = 0.08m$

**West Line**

Mean $\Delta E = -0.22m$ Mean $\Delta N = -0.08m$
USBL Comparison with conventional array calibration

Mean $\Delta E = 8.4$ feet (2.56m)
Mean $\Delta N = -11.6$ feet (-3.53m)

This equates to positional difference of 14.3 feet in 4,300 feet water

**I.E. 0.3% SLANT RANGE.**
• Proved improved performance capabilities of Wideband USBL.

• Proved operation of new Telemetry Schemes for faster Compatit commands – FSK

• Proved High Speed Telemetry Link

• Proved Array Box-in is a viable method for array calibrations in some situations.

• FUSION hardware and new wideband signaling technology allows a flexible approach to positioning and telemetry requirements.
Positioning in Ultra Deepwater OD 21 ‘Chikyu’
Positioning Performance in 4 500m

**REPEATABILITY 0.02% SLANT RANGE WITH MULTIPLE REFERENCES**

**ACOUSTICS ONLY TO SINGLE BEACON 0.1%**
Conclusions
Conclusions

• The use of Signal Processing relies on analogue carrier and it’s detection.

• Wideband greatly improves performance of current systems.

• Sound Velocity variations within the water column will continue to affect the transmission of signals – wideband or tone.
  
  – Effect of sound velocity variations is greatest when signals received from transponders at large horizontal offsets.
  
  – This will also be the condition when noise will be at a maximum, the signal will arrive at the same level as the thrusters.
• Wideband allows DP vessel operators to improve the performance of their acoustic position reference and reduce downtown due to lack of stable position references.

• Improvements come from:
  - Improved range measurement and repeatability
  - Removal of Interference
  - Robust operation
  - Extended Transponder Battery Life
  - Greater Flexibility
  - Faster Set-up and Operation
For more information please visit

www.sonardyne.com