SYNCHRONIZATION FOR EXPLORATION

Sonars
- EK Suite – 18 kHz (CW), 38 kHz (CW), 70 kHz (CW/FM), 120 kHz (CW), and 200 kHz (CW)
- Multibeam – EM302 (30 kHz)
- Subbottom – Knudsen 3260 (3.5 kHz)

NOAA Ship Okeanos Explorer
Effect on EK water column data from the EM 302 changing between CW and FM mode when it moves from DEEP 1 to DEEP 2 at ~ 1000 m

NEED TWO SYNCHRONOZATION SCENARIOS: ‘SHALLOW’ and ‘DEEP’
## Quick Guide to EM-302 Ping Modes and Sector Characteristics

<table>
<thead>
<tr>
<th>Ping Mode</th>
<th>Depth Range</th>
<th>Typical Coverage</th>
<th>TX Pulse (ms)</th>
<th>Frequency (kHz)</th>
<th>Port Sectors</th>
<th>Starboard Sectors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shallow</td>
<td>10 - 250</td>
<td>150</td>
<td>75</td>
<td>0.7 ms</td>
<td>0.7 ms</td>
<td>0.7 ms</td>
</tr>
<tr>
<td>Medium</td>
<td>750 - 750</td>
<td>150</td>
<td>75</td>
<td>26.5 kHz</td>
<td>30.5 kHz</td>
<td>32.5 kHz</td>
</tr>
<tr>
<td>Deep 1</td>
<td>750 - 1000</td>
<td>150</td>
<td>75</td>
<td>27 kHz</td>
<td>30 kHz</td>
<td>28.5 kHz</td>
</tr>
<tr>
<td>Deep 2</td>
<td>1000 - 3300</td>
<td>150</td>
<td>75</td>
<td>27 kHz</td>
<td>30 kHz</td>
<td>28.5 kHz</td>
</tr>
<tr>
<td>Very Deep</td>
<td>3300 - 5000</td>
<td>104</td>
<td>52</td>
<td>26.5 kHz</td>
<td>27.5 kHz</td>
<td>28 kHz</td>
</tr>
<tr>
<td>Extra Deep</td>
<td>5000 - 7000</td>
<td>70</td>
<td>35</td>
<td>26.5 kHz</td>
<td>27.5 kHz</td>
<td>28 kHz</td>
</tr>
<tr>
<td>Extra Deep</td>
<td>7000 +</td>
<td>36</td>
<td>18</td>
<td>26.5 kHz</td>
<td>27 kHz</td>
<td>28 kHz</td>
</tr>
</tbody>
</table>

*Leave Max Angles open unless outer-beam issues occur.*

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![Waveforms](image)
## TWO MAIN SYNCHRONIZATION SCHEMES

<table>
<thead>
<tr>
<th>SHALLOW (CW)</th>
<th>DEEP (FM)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>DEPTHs:</strong>  $\sim &lt;1000\text{m}$</td>
<td><strong>DEPTHs:</strong>  $\sim &gt;1000\text{m}$</td>
</tr>
<tr>
<td><strong>EM MODES:</strong> Shallow, Medium, Deep 1</td>
<td><strong>EM MODES:</strong> Deep 2, Very Deep, Extra Deep</td>
</tr>
</tbody>
</table>
SHALLOW (CW)
Profile: Shallow <1000 (CW mode)
When in depths < 1000 m, the optimal synchronization for maximum ping frequency and minimum interference is to have all sonars synchronized to trigger at the same time.
DEEP (FM)
NO WAY TO BOTH MAXIMIZE PING DENSITY AND REMOVE INTERFERENCE WHEN BOTH EM AND EK ARE IN FM MODE

MUST CHOOSE A TRADEOFF BASED ON OPERATIONAL PRIORITIES
**DEEP FM MODE OPERATIONAL TRADEOFFS (with EK 70 kHz)**

**Severely Degrades EM 302**
- Disable FM in EM

**Delay in EK**
- Shift interference to a noncritical part of the water column (in EK80 software)
- Operationally intensive and site specific; delay depends on depth

**Group (Ksync)**
- Sequential triggering minimizes interference among systems, but degrades ping density in both EM and EK

**EK CW Mode**
- Minimizes interference from EM, but loses wideband advantage of WBT(s)
- Could be good for normal operation in deep modes

**Keep Synced**
- EM destroys much of the EK80 70 kHz upper water column (100s of meters) when in FM mode (45-90 kHz)

**Tradeoffs**
- Degrades bathy, but highest frequency and least interference in EK 70 kHz in FM mode
- Useful for targeted EK FM operations, especially over previously mapped areas
1. Disable FM in EM302
2. Synchronize all sonars to fire at once
3. Disable FM in EK80 70 kHz
4. Delay EK in EK80 software
5. Group in KSync
Useful Scenarios:
When water column is of a higher priority than bathy (e.g., previously mapped areas).

Operation: Disable FM in EM302.

PROS
- Preserve high resolution FM EK 70 throughout the water column

CONS
- Deep EM302 modes unable to utilize benefits of FM for coverage
- Unable to use some EM modes, and therefore limits which depths bathy can be collected.

Useful Scenarios:
When water column is of a higher priority than bathy (e.g., previously mapped areas).
Operation: Keep EK80 70 kHz (FM) and EM302 synced to trigger at the same time.

**PROS**
- Does not interfere with EM302
- Easy operationally, as nothing changes from shallow to deep operations

**CONS**
- Completely destroys EK80 70kHz upper water column
- High data storage for partly usable record

**Useful Scenarios:**
Could be used if only interested in gathering FM EK data in deeper parts of the WC, beyond the region of interference.
**Operation:** Turn EK80 70 kHz from FM to CW mode.

**PROS**
- Does not interfere with EM302. Preserves ping density.
- Provides full depth range water column data in CW

**CONS**
- Unable to utilize benefits of FM for EK 70 kHz

**Useful Scenarios:**
Could be useful for normal operations as it provides useful water column data and does not degrade sounding density.
Useful Scenarios:
Useful for specific operations, such as only interested in upper water column.

**Operation:** Set a delay from EM trigger in EK software. Keep EK in FM mode.

**PROS**
- Moves interference into noncritical part of the water column.
- Preserves FM record in area of interest and data density.

**CONS**
- Still degrades some part of the EK record.
- Operationally intensive as it will be site, depth, and purpose specific.
- High data storage for partly usable record

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**Delay in EK**

**Useful Scenarios:**
Useful for specific operations, such as only interested in upper water column.
**Useful Scenarios:**
If you are willing to decrease bathy sounding density for full FM water column record.

**Operation:** Trigger EM and EK in separate groups using Ksync.

**PROS**
- No interference in both the EM and EK

**CONS**
- Decreases ping frequency of the EM and the EK. (See next slide)

**Useful Scenarios:**
If you are willing to decrease bathy sounding density for full FM water column record.
Profile: Deep >1000 (FM mode) 2 Groups
### Effect of Grouping on EM Sounding Density

<table>
<thead>
<tr>
<th>Depth (m)</th>
<th>Ping Rate (1) (s)</th>
<th>Ping Rate (2) (s)</th>
<th>Alongtrack Spacing (1) (m)</th>
<th>Alongtrack Spacing (2) (m)</th>
<th>% Increase</th>
</tr>
</thead>
<tbody>
<tr>
<td>500</td>
<td>3.417</td>
<td>5.445</td>
<td>14</td>
<td>22</td>
<td>59</td>
</tr>
<tr>
<td>1500</td>
<td>6.342</td>
<td>8.849</td>
<td>26</td>
<td>36</td>
<td>40</td>
</tr>
<tr>
<td>2000</td>
<td>7.888</td>
<td>10.598</td>
<td>32</td>
<td>44</td>
<td>34</td>
</tr>
<tr>
<td>2500</td>
<td>8.552</td>
<td>12.101</td>
<td>35</td>
<td>50</td>
<td>41</td>
</tr>
<tr>
<td>3000</td>
<td>9.636</td>
<td>13.189</td>
<td>40</td>
<td>54</td>
<td>37</td>
</tr>
</tbody>
</table>

Change in alongtrack spacing with 2 groups vs 1 (estimating as single swath at 8 kts)
Sonars

EK Suite – 18 kHz (CW), 38 kHz (CW), 70 kHz (CW/FM), 120 kHz (CW), and 200 kHz (CW)
Multibeam – EM302 (30 kHz)
Subbottom – Knudsen 3260 (3.5 kHz)

SHALLOW (CW MODE)

EM Modes: (V) Shallow, Medium, Deep
Depth Range: 0 – 1000 meters

OPERATIONS

All sonars should be synced to trigger at the same time, with the EM302 set as the master. This will maximize ping density and minimize interference for all sonars.

DEEP (FM MODE)

Depth Range: 1000+ meters

OPERATIONS

*Tradeoff based on operational priority.*

Normal Operation: EK80 70 kHz in CW mode.

Operation Specific: Separate Groups for EM and EKs, Delay EKs, or Disable FM/Turn off EM 302
Factors that unnecessarily increase ping rate:

- Minimum Ping Rate on EKs (due to duty cycle?)
  18 kHz (8 ms) = 1.64 seconds
  18 kHz (.864 ms) = 1.64 seconds
- A frequency not able to detect the seafloor (with bottom detect ON)
- Too large of a Window Range
- Too large of a Record Range
THANKS!

Kevin Jerram, Multibeam Advisory Committee, University of New Hampshire

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Gregg Juergens, Kongsberg Underwater Technology