The Application of Wideband Signals in Fisheries and Plankton Acoustics

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Abstract: Over the last thirty years, there have been considerable improvements in the techniques developed for doing acoustic assessment of fisheries and plankton populations. The techniques have evolved from analog echo integrators used to obtain crude abundance estimates, to multiple beam techniques for measuring the in situ target strength, location and velocity of individual targets. These advancements have been largely due to advancements in the digital signal processing techniques used to process the echoes out of the sounder. The same basic signal type, the sine wave pulse, has been used in nearly all plankton and fisheries assessment systems during all these post-processing developments. The same digital processing technology that has enabled the evolution of these post processing advances is now finding its way into the echo sounder. In particular, biological assessment echo sounders that use FM slide/chirp signals with time-bandwidth products of up to fifty have been developed and implemented. These systems provide a signal-to-noise advantage in excess of 15 dB when compared to sine wave pulse signals with the same spatial resolution.

FM SLIDE VERSUS SINE WAVE PULSE

Acoustic systems used for monitoring fish or plankton populations must often have both good range resolution and a good signal-to-noise ratio. The range resolution is required for both in situ target strength measurement of individual scatterers, and investigations of the fine-scale structure of scattering layers. Unfortunately, it is not always possible to achieve both good range resolution and good signal-to-noise ratios with conventional echo sounders using sine wave pulse type signals. In these conventional systems the range resolution is inversely proportional to the transmitted pulse length, while the signal energy, and therefore the signal-to-noise ratio, are directly proportional to the pulse length. The signal-to-noise can be increased by increasing the transmitted pulse length, but this reduces the resolution. Fortunately, there is a way around the dilemma of signal-to-noise versus spatial resolution encountered with sine wave pulse echo sounders. The solution uses a signal called an FM slide or chirp. The frequency of the carrier frequency is varied linearly within the pulse. When properly processed using a technique called matched filtering, the range resolution achieved with the FM slide signal is inversely proportional to the bandwidth of the frequencies swept. Therefore, with an FM slide signal, the range resolution can be controlled independently of the signal energy. The signal-to-noise improvement of an FM slide signal over that of a conventional sine wave pulse signal is called the processing gain, G, and is equal to the product of the pulse duration and the frequency range swept. For example, a 5 ms pulse with a 10 kHz frequency sweep will provide a signal-to-noise that is a factor of 50 (17 dB) greater than a sine wave pulse signal with a 0.1 ms pulse length. Both signals will have the same spatial resolution. The 17dB improvement in signal-to-noise effectively increases the useful sampling range by factor of 2.6 over that of a sine wave pulse echo sounder with the same transmit power.

FM SLIDE IMPLEMENTATION

FM slide technology is not new. Military radar and sonar systems have been using wide band signals, such as the FM slide, for nearly 50 years. Until recently, the cost and complexity of the electronics required to implement the matched filter receivers kept wide band signals from being used in echo sounders developed for fisheries and plankton assessment. The processing power provided by high speed digital signal processing chips has changed this. The HTI Model 240-Series Split Beam Echo Sounder systems use multiple digital signal processing chips to implement the processing functions that were previously implemented with discrete analog and digital components. As a result of the flexibility provided by this approach, the echo sounders can be configured to use either conventional sine wave pulse or FM slide signals with processing gains up to 50 (17 dB).

One of the problems that can be encountered when using an FM slide signal is that large targets can produce smaller false targets that are shifted in range. These false targets are caused by range lobes in the
response of the matched filter. Radar engineers developed a technique called frequency domain windowing to deal with this problem (1). The echo sounder developed by HTI has also implemented this technique for minimizing range side lobes. The side lobes in the matched filter output are suppressed by at least 35 dB.

APPLICATIONS

FM slide-based echo sounders will have their greatest benefit when the system performance is primarily limited by additive noise rather than by reverberation. Additive noise is usually the limiting factor for open-water acoustic systems used to detect and quantify targets at long range from the transducer, or for assessment of very small targets such as plankton at nearly all ranges.

The advantage of the FM slide signal is illustrated by comparing the echograms collected with both the FM slide and sine wave pulse signal. Figure 1 shows an echogram collected with the HTI Model 244 multi-frequency system developed for Woods Hole Oceanographic Institution. Note that the noise dominates the echogram output at longer ranges for the tone-burst pulse signal. The FM slide suppresses the noise and provides a clean echogram over the entire depth range.

![Echogram showing the relative performance of the FM slide and sine wave pulse signals](image)`

FIGURE 1. Echogram showing the relative performance of the FM slide and sine wave pulse signals

REFERENCES