Modified Shifted Sideband Beamformer for Swath Bathymetry Sonar

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Abstract: This paper first analyses the problems of Shifted Sideband Beamformer (SSB) used in the swath bathymetry sonar and then raises an optimal digital quadrature transform technology so as to achieve the quadrature signal in complex low-pass form. The configuration and realization approach of this digital quadrature transform are discussed. Lastly some sea trial results show that the method is right, efficient and universal for active sonar.

INTRODUCTION

In recently years, along with the ocean developing and sailing safe requirements, the plenty of swath bathymetry equipment have been installed in ships. To obtain high resolution and coverage range, in the multi-beam swath bathymetry system the real-time multi-beamformer must be realized. The digital beamformers are widely used in modern sonar because consistency beam steering, high stability, easy adjusted, small volume and programmable, but when there are a lot of array elements or beams, the computing amount is very huge. In our developing multibeam swath bathymetry device, a new beamforming structure, referred to as the modified shifted sideband beamformer (MSSB) has been adopted in order to reduce computing amount of real-time signal processing in this frequency system and to simplify hardware complexity.

MODIFIED SHIFTED SIDEBAND BEAMFORMER

The Shifted Sideband Beamformer (SSB) in reference[1] is excellent method to process available bandpass signal from the array sensors. It has combined the time-domain beamforming with frequency-domain beamforming, in lower sampling rate its performance is near conventional time-domain beamformer of high sampling rate. Its computing amount and hardware complexity are reduced. The configuration of SSB is shown in Fig. 1. The key technique to realize this beamformer is complex demodulation. Conventional analog complex demodulation method requires that the signals of two analog channels are adjusted to keep the gain and phase balanced, otherwise the in-phase and quadrature errors are to influence the maximum response axes(MRA) and beamwidth as well as the structure of sidelobe. Therefore, here the optimal digital complex demodulation method is adopted. It improves the in-phase and quadrature errors as well as the beam directional precision and simplifies the hardware structure. The beamformer based on the optimal digital complex demodulation is called as the MSSB.

The Modified Shifted Sideband Beamformer configuration is obtained from Fig. 1(excluding inside dashed frames). It adopts only single channel analog multiplier and single A/D converter. After sampling, the quadrature component is obtained by way of a digital quadrature transform. For M received channels this method may save M channels of 90°phase shifters, analog multipliers, low-pass filters and A/D converters. The major point of MSSB is a digital quadrature transform because its precision and computing amount determines that the whether or not MSSB is realized truly and the performance of beamformer. In the next section, the realization approach of the digital quadrature transform (Hilbert transform) is discussed. To go through optimal designing, the performance of
the quadrature component only depends on the coefficients of Hilbert transform and the approach is easily realized with high speed DSP device. Hence, it is necessary to emphasize the method obtained the optimal Hilbert transform coefficients.

**OPTIMAL DIGITAL HILBERT TRANSFORM**

According to the definition of ideal Hilbert network, the Hilbert transform is corresponding with a 90° phase shifter. It is clearly that the ideal Hilbert transform is unrealizable since its impulse response is doubly infinite in extend, thus the ideal Hilbert transform is as the ideal low-pass filter in that such filter can never be realized exactly in practice. So we consider that realizable approximations to this filter should be designed in practice. In our design, we will use the Chebyshev approximation method that can use the Remez exchange algorithm. Considering the principle, we design a linear phase FIR filter. In order to obtain the optimal impulse response of FIR Hilbert transformer, the following condition should be satisfied:

(a) FIR filter design by Chebyshev approximation
(b) The lengths of FIR filter N is odd, generally, (N-1)/2 is also odd
(c) $\Delta F = F_L - 0.5 - F_H$ is set

where $F_L$ represents the lower cutoff frequency and $F_H$ represents the higher cutoff frequency of the band for which the filter approximates the ideal Hilbert transformer response, $\Delta F$ is transition bandwidth. The larger the values of $N$ and $\Delta F$ are, the smaller the value of $\delta$ (The peak approximation error of the filter). So we should choose $N$ and $\Delta F$ as large as possible and select an odd value of $N$. In our multibeam bathymetry system, after some factors are taken into account, such as: frequency bandwidth, operational capacity of processors, permissible errors of amplitude and phase between quadrature signals, we choose the parameters as: $N$ is 19, $\Delta F$ is 0.1, then $\delta \leq 0.001$. When $N$ and $\Delta F$ is defined, we can apply Remez exchange algorithm to calculate the impulse response $h(n)$ of Hilbert transformer.

**RESULTS AND CONCLUSIONS**

The hardware implementation of MSSB is accomplished based on MIMD architecture that takes TMS320C30 DSP. The sea trial results of MSSB are shown in Fig. 2. These results show that the quadrature transform presented in the paper is characterized by high accuracy, less sampling rate and less computation, easily realized with high speed DSP device. Although the implementations provide here is in view of multi-beamforming for multibeam swath bathymetry survey system, it can be expected that this method should be fit for other active sonar.

![FIGURE 2 The energy envelope output of MSSB](image)

**REFERENCES**