CORRECTION OF FREQUENCY DISTORTION OF THE DDS SIGNALS

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The Diver Detection Sonar (DDS) as a surveillance system has been designed to monitor the threat of underwater attacks against harbours, ships, naval bases, coastal industrial installations, oil platforms etc.

This paper describes technical complexity of designing wideband DDS, with increased coverage effectiveness and following additional advantages: improved range resolution, high signal to noise and reverberation ratio and possibility operation of several sonars in the same frequency band using different type of modulation.

The article presents technological principles and problems related to the wideband signals transmitting and receiving by cylindrical piezocomposite transducer as well as implementation of the broadband compression technique for correction of frequency distortion.

INTRODUCTION

The FAT performed by Materials Systems Inc. (manufacturer of the piezocomposite DDS array) points to spread of source level (SL) of individual elements of DDS array – see Figure 1. Strong fluctuation of SL attained to 8 dB at 70 kHz, 6 dB at 60 kHz and 5 dB at 80 kHz frequency may cause considerable problem during forming of group beam patterns. The solution of the problem is averaging of SL fluctuation. It has been carried out by parallel connection of 8, 16 and 24 elements and each elements group is supplied from one power source.

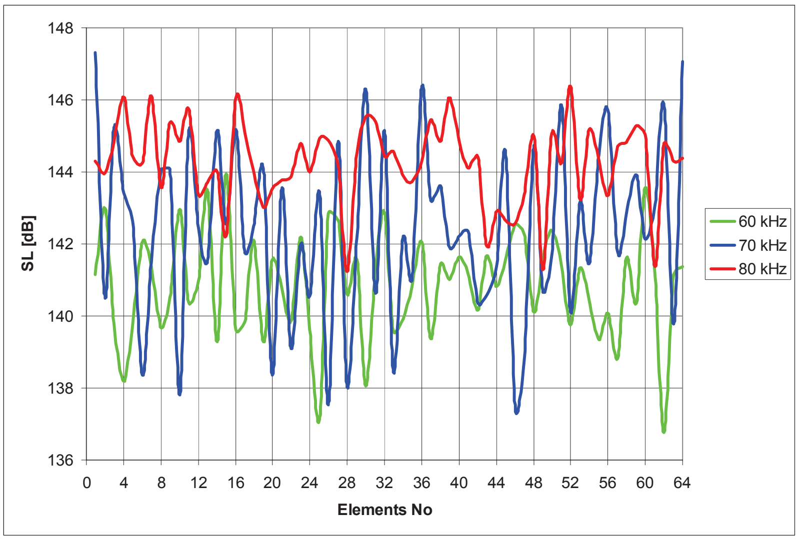


Fig.1. Source level (SL) of the 64 elements of the DDS array for 3 frequencies

Results of this for 16 elements group are shown in Figure 2. It is evident that beam pattern begin "composed" and rated SL has been achieved. FAT depicts also Receive Voltage Sensitivity (RVS) depends on frequency and for every individual element is different from the others – see Figure 3. This phenomenon is the same as for transmitting and may disadvantageous affects on DDS operation. The present article related to means of this disadvantageous effects minimization.

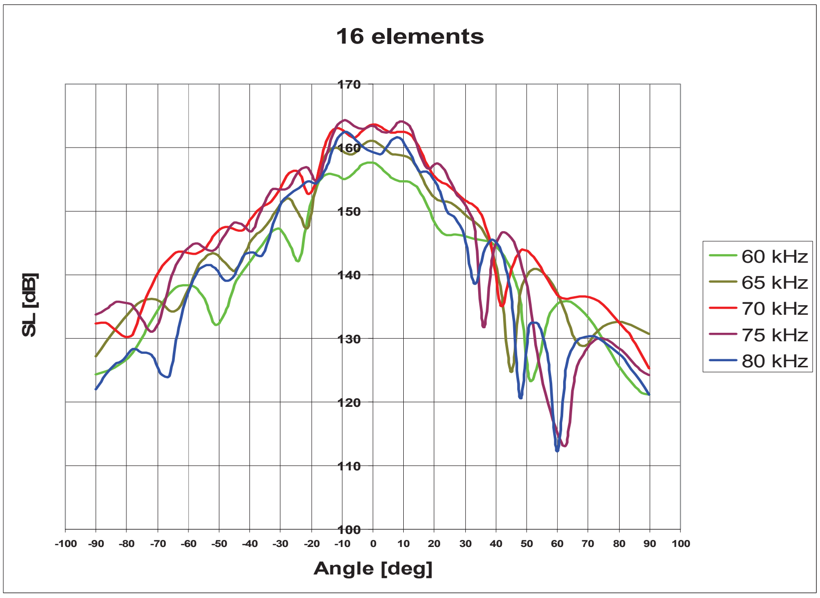


Fig.2. Transmitting beam patterns of DDS cylindrical array for 5 frequencies

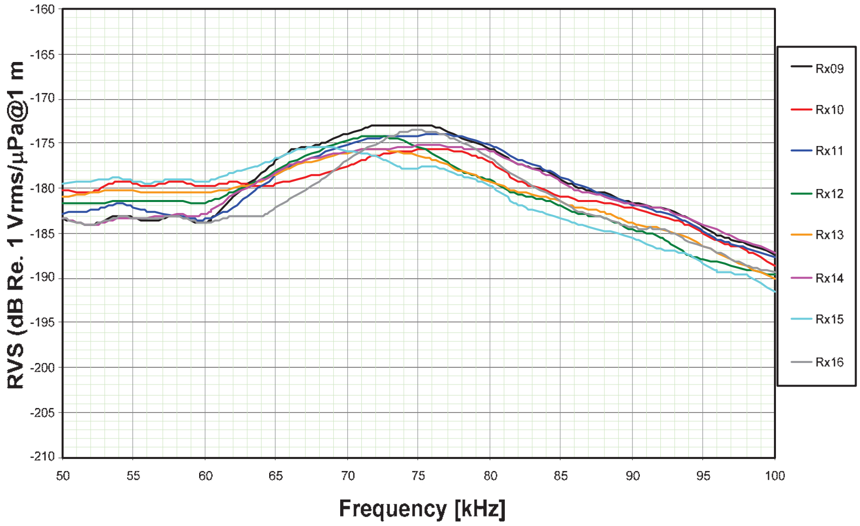


Fig.3. Receive Voltage Sensitivity (RVS) versus frequency for 8 selected elements

1. CORRECTION OF SIGNAL FREQUENCY DISTORTION BY CORRECTED REPLICAS APPLICATION

The analysis of elements frequency characteristics (SL and RVS versus frequency) displays signal level decrease up to 12 dB on the edges of DDS band (60 kHz ÷ 80 kHz). Smoothing of the characteristics may be done by using, in correlation processing, proper corrected replicas. For correction of distortion, signal with $\cos^2$ envelope and 3, 6, 9 or 12 dB pedestal as well as replicas with reverse envelope and 3, 6, 9 or 12 dB pedestal were applied. Signal with $\cos^2$ envelope and 3, 6, 9 or 12 dB pedestal represents real signal with falling band whereas replicas with reverse envelope is to be “response” on falling band. An example of used signals and replicas are shown in Figure 4.

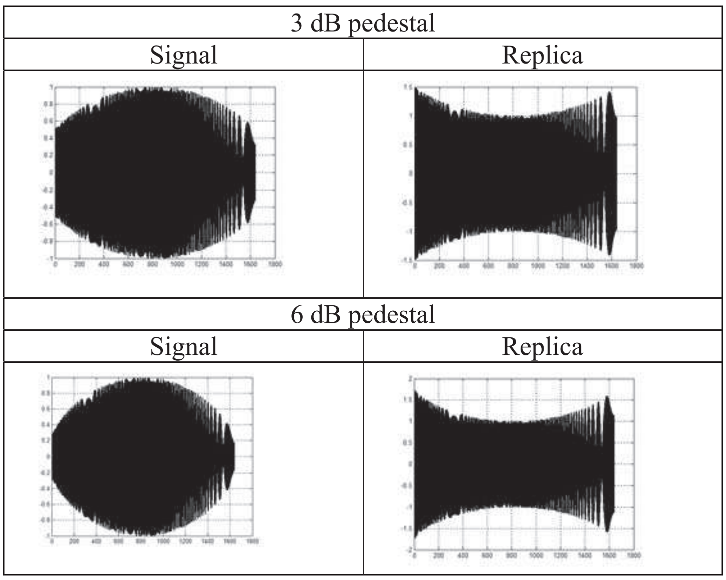


Fig.4. An example of used signals and their appropriate replicas

Results of correlation processing between signals of $\cos^2$ envelope with 3, 6, 9 or 12 dB pedestal and rectangular replica is shown in Figure 5.

A **B**

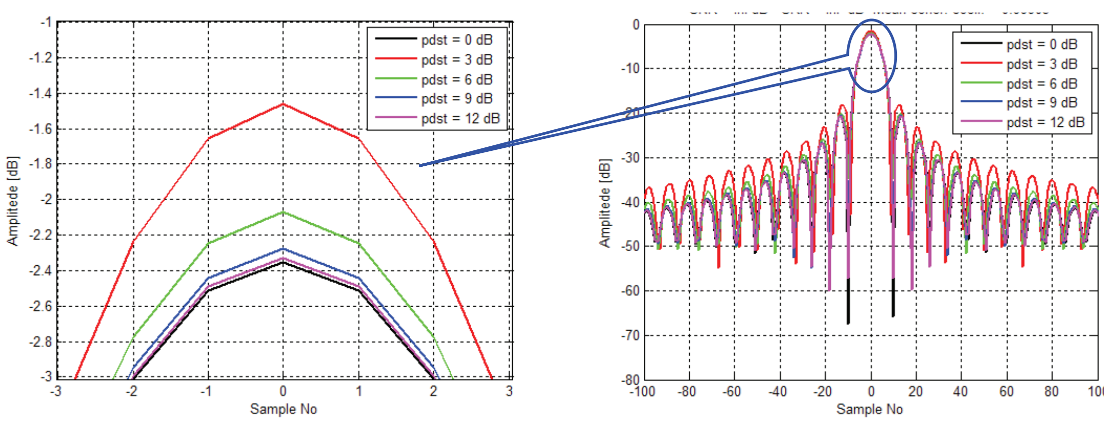


Fig.5. A and B Correlation between signal of $\cos^2$ envelope and replica of rectangular envelope. Figure A is the magnification of Figure B

The value of correlation coefficient maximum may be measure of efficiency of frequency distortion correction. Measurable advantageous arises from application corrected replicas are demonstrated in Figure 6. The figure shows maximal values of correlation between the signals with 3 dB, 6 dB, 9 dB and 12 dB decrease levels at the band edges and rectangular and corrected replicas. It is clearly that corrected replicas bring approx. 1.2 dB profit. It is seemed also that replica with 3 dB pedestal will be sufficient to correct frequency distortion of all signals.

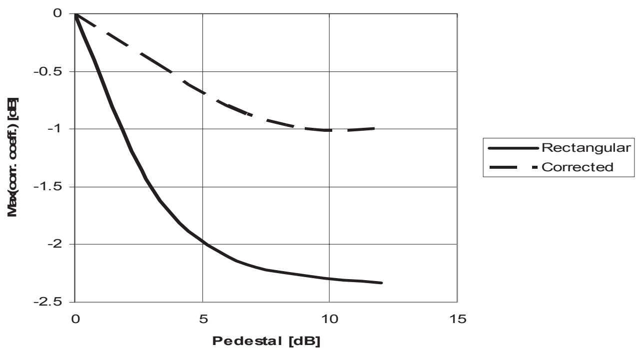


Fig.6. Maximal value of correlation coefficient as a function of pedestal

2. INFLUENCE OF NOISE

The analysis presented above has been performed for theoretical signals without noise. The analysis of noise influence on efficiency matched filtration used in data processing has been carried out also. White noise with specified variance has been added to signal and next correlation processing with corrected replica has been made. The results of the analysis demonstrate that:

– matched filter provides very much separation of target echo from signal analyzed when SNR ≥ 0, since the level of side lobes related to false target is lesser then -20 dB,

– efficiency of corrected replica decrease of 1 dB when signal frequency distortion increase from 3 dB to 12 dB,
– when SNR ≤ -1.5 dB, side lobes with level of greater than -20 dB may appears what may means an appearance of false target.

Figure 7 presents an example of analysis result. The analysis covers also influence of noise on the correspondence between signal and corrected replica at each frequency in DDS band. The influence was estimated using function spectral coherence and next calculated mean coherence coefficient (MCC) in DDS band (20 kHz) – MCC is a average of 50 iteration. Result of this is shown in Figure 8 – as expected, MCC logarithmic decrease when noise increase.

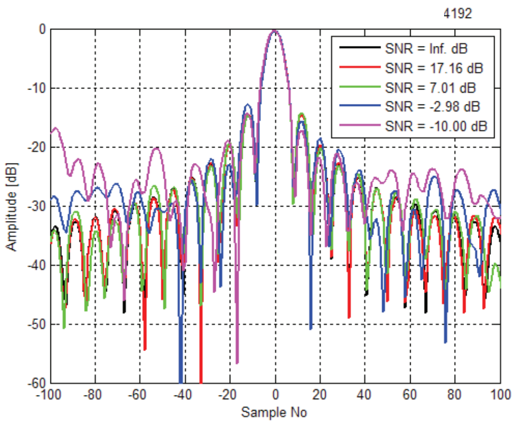


Fig.7. Correlation between signal ($\cos^2$ envelope, 3 dB pedestal, noise) and corrected replica

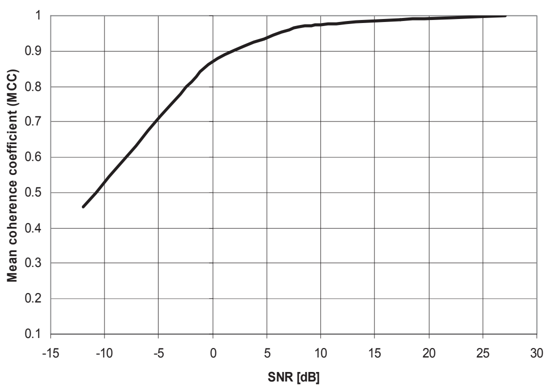


Fig.8. Mean coherence coefficient versus SNR

3. INFLUENCE OF REVERBERATION

In our study, the reverberation was simulated as additional signals, with random phase and amplitude, which sums (with phase shift) with target echo before the matched filtration [1]. For the reverberation, signal to reverberation ratio (SRR) and coherence coefficient (KR) was calculated. Figure 9 displays an example of reverberation modelling – random distributed reverberation with random amplitude. The influence of reverberation has been measured by number of false target exceeding -20 dB level in relation to reference level (target level).

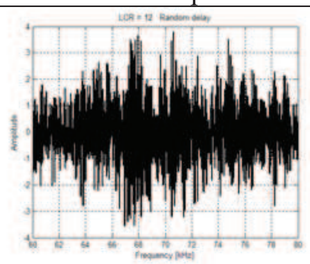
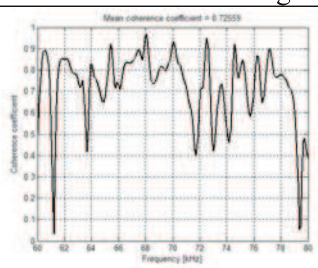
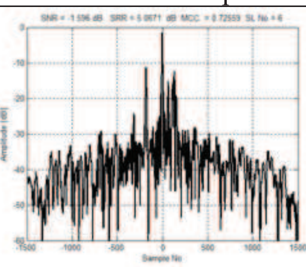
Received signal at MF input	Coherence between of received and reference signal	Correlation of received signal and corrected replica
		

Fig.9. An example of reverberation modelling
Number of scattering points = 12, delay = random, SNR = -1.46 dB, amplitude = random

In conformity with expectations the number of false targets (FT) and their levels (see Figure 10) logarithmic increases when number of scattering points grows.

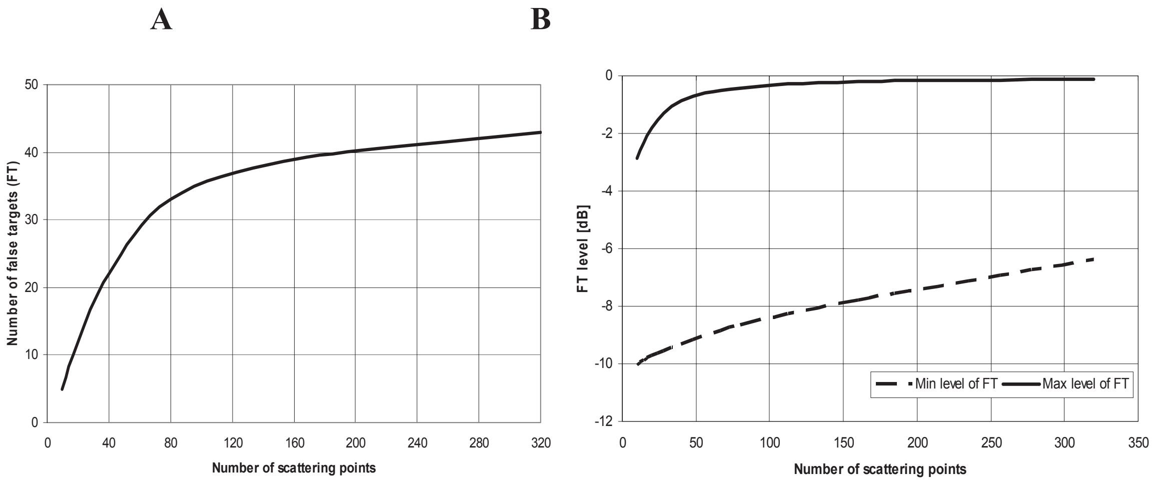


Fig.10. Number of false targets (**A**) and their levels (**B**)
versus number of scattering points

4. CONCLUSION

1. The results of a numerical simulation presented above suggested that the applied of corrected replicas in correlation processing may be used for effective correction of signals DDS frequency distortion. It is seemed also that replica with 3 dB pedestal will be sufficient to correct frequency distortion of all signals.
2. Results of analysis influence of noise and reverberation on DDS effectiveness indicates false target may appears when SNR is lesser then -1.5 dB whereas even single reverberation may be a false target dependent on much geoacoustic parameters for bottom reverberation and mainly wind velocity for sea surface reverberation [2]. As expected number of false targets logarithmically increased when number of scattering points linear increases.
3. Presented results should be confirmed by experiments in real environmental conditions.

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