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MODELING OF NARROW AND WIDEBAND SIGNALS SCATTERING BY RANDOMLY DISTRIBUTED SCATTERING POINTS

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Presented in the paper issue of surface and volume scattering of acoustic wave in marine environment is fundamental problem related to mono-, bi- and multistatic acoustic systems operating in littoral sea. Reverberation creating as a result of the scattering has a significantly influence on the small target detection. Modeling of narrow and wideband signal scattering has been carried out using MATLAB. To solve the issue we accepted that scattering occurred on randomly distributed points which generated scattering waves received and summed in receiver. Density and arrangement of the points is a measure of environment scattering property. The analyses, by signal processing in matched filter, were made for LFM, HFM and CW signals (for comparison). The effect of signal parameters on scattering was investigated also.

Keywords: scattering, reverberation.

1. Introduction

Scattering of acoustic waves by rough surfaces (bottom and surface of acoustic duct) are generally the dominant interference sources for active acoustic systems operates in littoral waters. The knowledge of this scattering (especially in forward direction) is a essential issue concerned with the current research project relating to active bistatic acoustic barrier intended to littoral waters (harbour, anchorage). Due to large number of the geophysical and environmental parameters, approximation methods i.e. Kirchhoff approximation (KAM) or small-slope approximation (SSA) are mostly used in the scattering models [1, 2]. It is noted a long history of scattering investigation covers mainly backscattering (bistatic angle $(\Theta_{\mathrm{bi}}) = 180°)$, but scattering for rest Θ_{bi} is rather weak developed. This paper presents the analysis of scattering influence for different type of signals which may be applied in bistatic acoustic barrier. The analyses based on simplificated scattering mode have been done at following assumptions:

- scattering geometry as in Fig. 1,
- scattering surface is presented by randomly distributed scattering points (SP) – for comparable signals simulations, scattering point was uniformly distributed,

- scatterings points generates isotropic wave,
- scattering parameters of surface are determined by quantity of scattering points and an amplitude of scattered rays,
- scattered rays are summed in receiver and then processed by matched filtration,
- inpinging rays are rectangular pulses with linear and hyperbolic modulation,
- comparably pulse is CW,
- parameters of the LFM signals are: $f = 60$ kHz, $B = 20$ kHz, $\tau = 20$ ms.

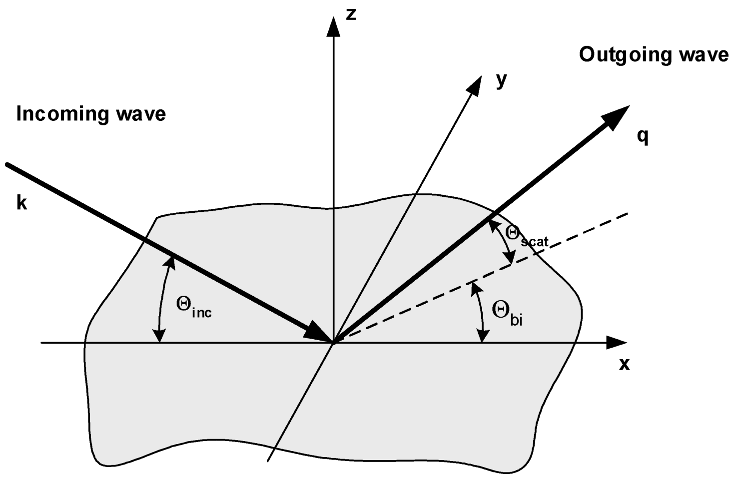

Fig. 1. Geometry of scattering. Θ_i – incident angle, Θ_s – scattered angle, $\Theta_{\rm bi}$ – bistatic angle, **k** and **q** are the incoming and outgoing wave vectors.

One should be noted, that hitherto existing scattering models including the geophysical and environmental parameters (i.e. bottom roughness spectrum, wind speed) was developed for CW signals (up to 15 kHz) and not analyzed scattering from the point of view signal type – narrow or broadband. This work is attempt on the estimation of scattering depends on signal type.

2. Model illustrations

2.1. Uniformly distributed scattering points

Figure 2 illustrates elementary dependence of MF output versus phase spacing. Achieved results have been obtained by scattering simulation of 21 pulses with phase spacing between successive pulses changing from 0° to 1440° (in time unit, from 0 ms to 1.4 ms).

The simulations show that reverberation can be cut off by properly set up the threshold when pulses are LFM or HFM type. The threshold level depends on signal bandwidth (lower for wider B – see Fig. 3) and is independent from pulse length.

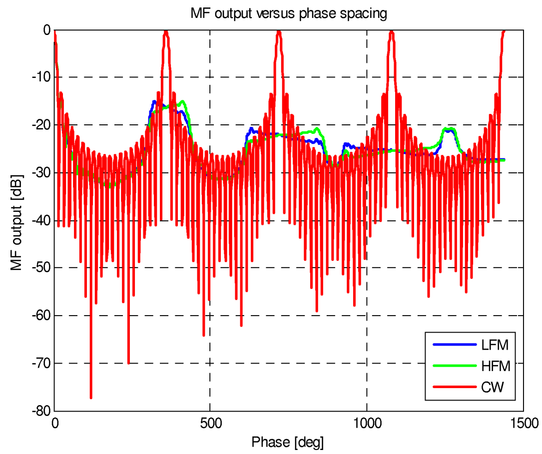

Fig. 2. Comparison of three type pulses on MF output. Phase spacing between 21 pulses is changed from 0° to 1440° (from 0 ms to 1.4 ms).

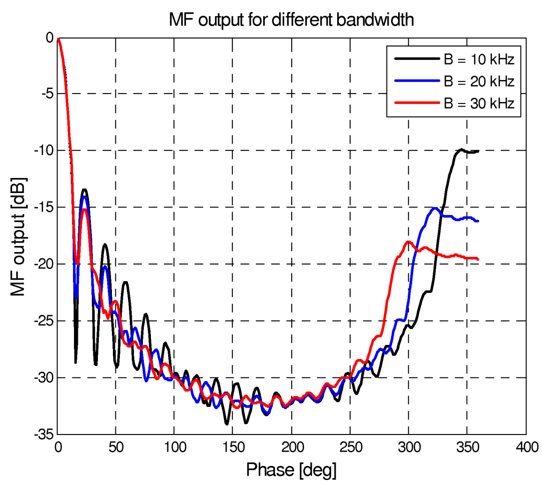

Fig. 3. MF output for three different bandwidth. Pulse type – LFM.

2.2. Randomly distributed scattering points

Successive analysis covers a real situation when scattering points are randomly distributed. The fluctuations of successive pulses delays have been simulated by Gaussian noise with different variances – phase spacing/noise ratio was identical at all investigated ranges. Examples of results are shown in Figs. 4 and 5.

The results of analysis displays that for delays greater than 0.5 μs ($\approx 10^\circ$ of phase spacing) the noise is prevailing on MF output, but her amplitude (peak to peak) is clearly smaller for LFM in comparison with CW and moreover the amplitude decreases when phase spacing (pulses delay) increases.

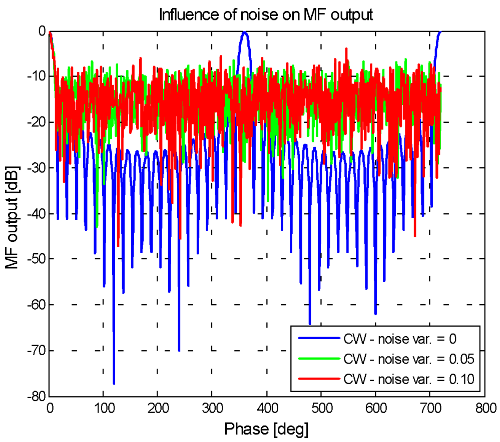

Fig. 4. MF output for three different noise variations. Pulse type – CW.

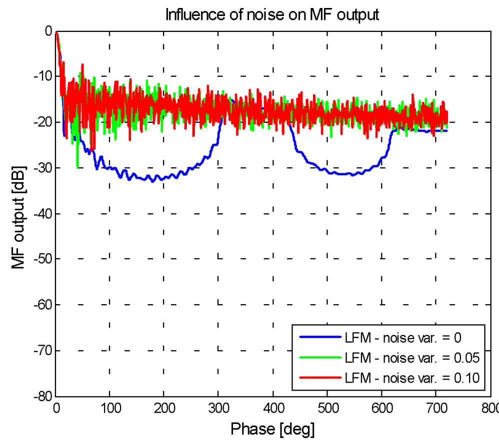

Fig. 5. MF output for three different noise variations. Pulse type – LFM.

2.3. *Modelling of scattering characteristic*

The scattering characteristics were modelled by density of scattering points and their scattering abilities. First is simulated by number of randomly distributed scattering points, second by randomly distributed pulses amplitude.

Figures, presented below, show a simulation results for two scattering models and two type signals: LFM (Fig. 6a) and CW (Fig. 6b). Abbreviations UDP, RDP and RAM means: UDP uniformly distributed points, RDP randomly distributed points and RAM randomly distributed amplitude. For (RDP + RAM) model, Gaussian noise with variance = 0.1 was applied and one pulse among 21 has not RAM.

a) b)

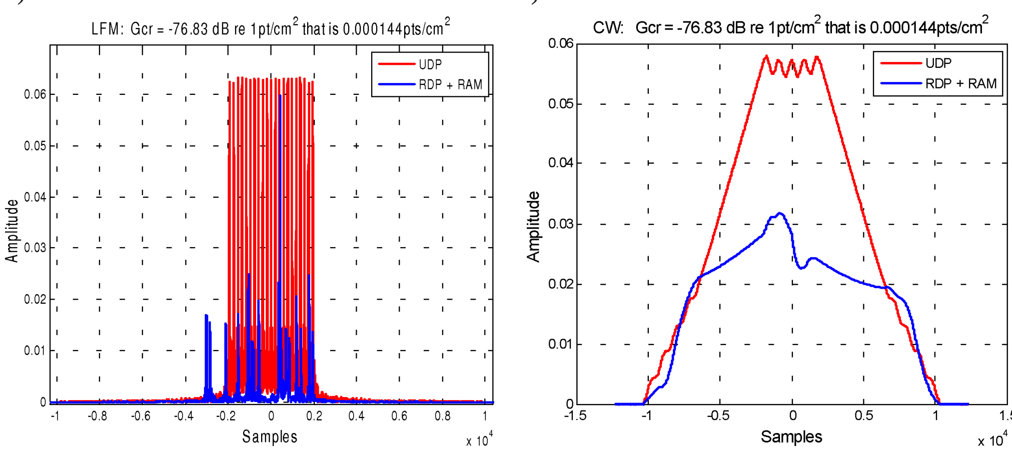

Fig. 6. Simulation of scattering surface for two models with points density = 0.000144 pts/cm^2: a) LFM, b) CW.

2.4. Statistics

To determine frequency of defined signal values occurrence, the histograms, with class number equal 10, for two scattering model have been made. The histograms contained also quantity of events (numbers in couloured rectangulars) in each class.

A. Model with uniformly distributed scattering points

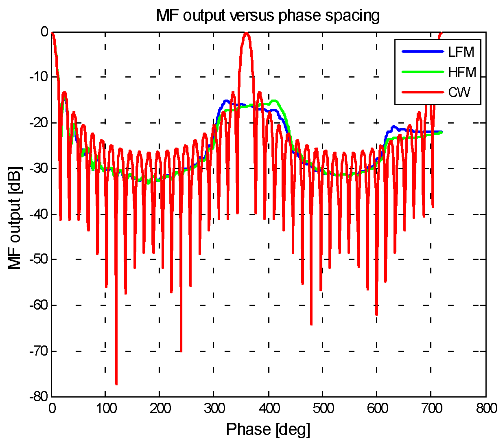

Fig. 7. MF output.

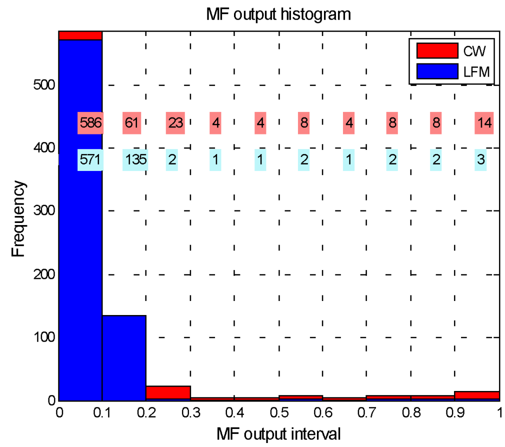

Fig. 8. Histogram of MF output (Fig. 7) together with quantity of event in each class.

B. Model with randomly distributed scattering points

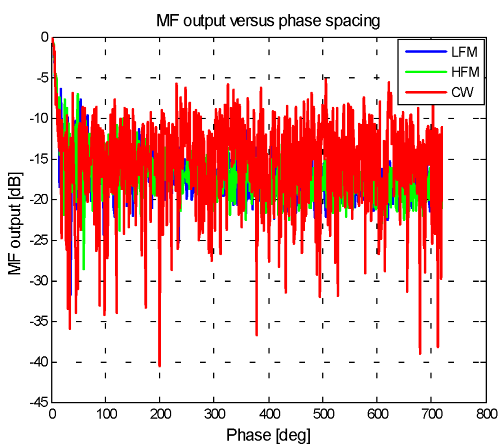

Fig. 9. MF output.

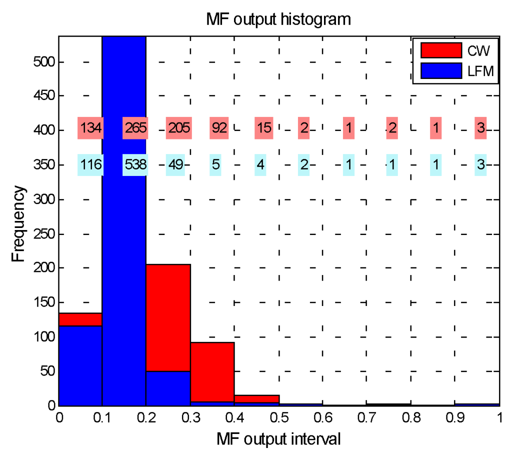

Fig. 10. Histogram of MF output (Fig. 9) together with quantity of event in each class.

The obtained histograms shows strong right-hand asymmetry of amplitude distribution, the asymmetry value of LFM signal is greater than for CW signal.

3. Conclusions

Due to a problem of modelling of acoustic wave scattering on rough sea bottom is very complex, the authors have been presented her simplified solution assuming the acoustic wave scatters are randomly distributed points, each with "own" scattering ability. The computer simulation of this scattering carried out for CW, LFM and HFM signals at parameters which will be used for designed active acoustic barrier, demonstrate that the model appears as useful tool for estimation of narrow and wideband scattering. Additionally it has been found that:

- threshold detection is more effective for LFM or HFM signal than CW (threshold detection level of LFM signals is approx. 5 dB smaller than for CW signal),
- decrease of scattering points density causes increase of signal length on the MF output as well as the echoes from particular points appears,
- target echo can be very effective separated from background noise (reverberations) by correlation processing,
- effectiveness of separation depends on signal bandwidth.

Acknowledgment

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