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Impact of Internal and External Interferences on the Performance of a FMCW Radar

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ABSTRACT: Although FMCW technology has become by now mature, there are still some unsolved problems left. First group of them are noise and distortion from own transmitter or receiver. They are usually caused by DDS (Direct Digital Synthesis) and power converters performance. They appear on radar display as circles or arcs because of their isotropic properties. Second group are interferences from external world like beams of pulsed radars working in the same frequency band, reflections from close buildings and installations or sea clutter. Apart from creating artificial echoes of target they can cause degradation of radar tracking system. This paper evaluates influence of internal and external sources of interferences on the FMCW radar performance. DSP (Digital Signal Processing) algorithms which optimize detection of FMCW radar were presented. Means of suppressing analog interferences by digital techniques were shown as well.

1 INTRODUCTION

There are two basic kinds of interferences which decrease a performance of FMCW radar. The first kind are noise and distortion of the own radar, second one are interferences coming from nearby buildings, sea clutter and other electronic equipment working in the same frequency band. There are some ways to couple with such a problem. Most of them are based on digital signal processing algorithms implemented in DSP processor code. Developing of CFAR (Constant False Alarm Ratio) detector looks as the best way of suppressing analog interferences. The radar works in X band. In DPU (Digital Processing Unit) 8192 point real FFT was applied as well as binary integration, correlation and a few kinds of CFAR including clutter-map. The antenna and transceiver of FMCW radar are shown in the figure 1.

Figure 1. FMCW radar

2 INTERNAL INTERFERENCES

Although manufacturers of radars try to achieve perfect spectrum performance, there is always small leakage of interferences coming from the transmitter and the receiver. Some unwanted products of digital synthesis and power converters appear in the IF (Intermediate Frequency) signal. Although the signal sampled in DPU (Digital Processing Unit) is band limited, some of the mentioned products remain in data vector after FFT (Fast Fourier Transform) processing. Having a level greater than background noises, they are detected and displayed as artificial echoes. Because interferences appear in the fixed frequency, they are seen as a circle or a part of the circle on the radar display (Fig. 2). Such kind of artifact can mislead radar operator and tracking system. Echoes of ships which are close to the circle would be probably undetected. Tracking of the object moving trough the interference area is frequently lost. There are some simple ways of suppressing such interferences. Firstly, we can increase the detection level. Unfortunately, in this case we reduce the detection probability of others echoes as well. It is also possibility to change carrier frequency of transceiver. Although the interference (circle) vanishes, another one often appears nearby.

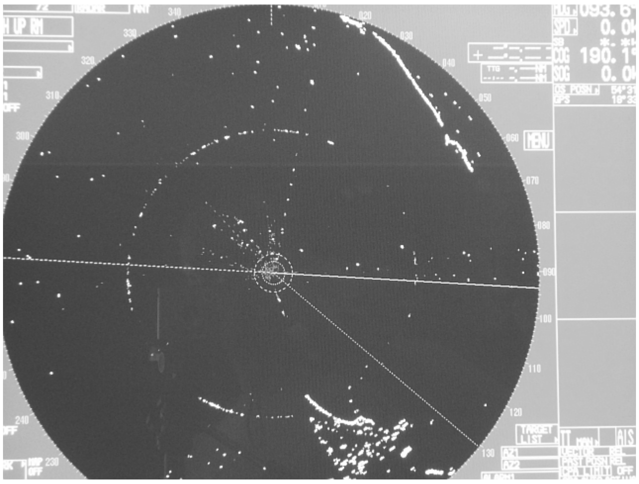

Figure 2. Circle-shaped interferences as a result of the own transmitter noise and a radial interference from the pulsed radar beam.

To analyze the problem from DSP point of view we should consider how CFAR algorithm works [3].

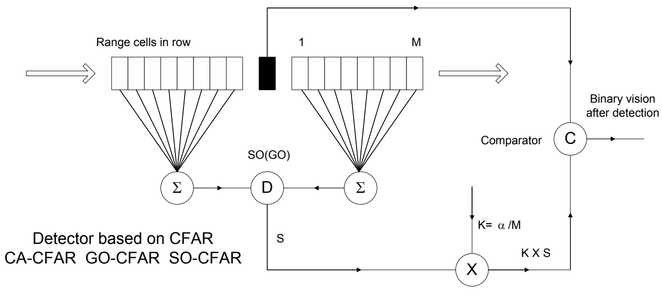

Figure 3. CFAR algorithm concept

The range-cell under test is compared with its neighborhood. If the value of the signal in the cell is greater then the average value of the neighborhood, detection occurs. Specific interference exists only in a few range cells in a row. If we found the right cell number, we could increase the CFAR level locally. Even though real echoes in those range-cells are suppressed as well, other range-cells are unaffected. This simple approach suppresses the interference just before detection. The results of applying such approach is shown in figure 4. The circle disappears, detection of nearby echoes is still possible.

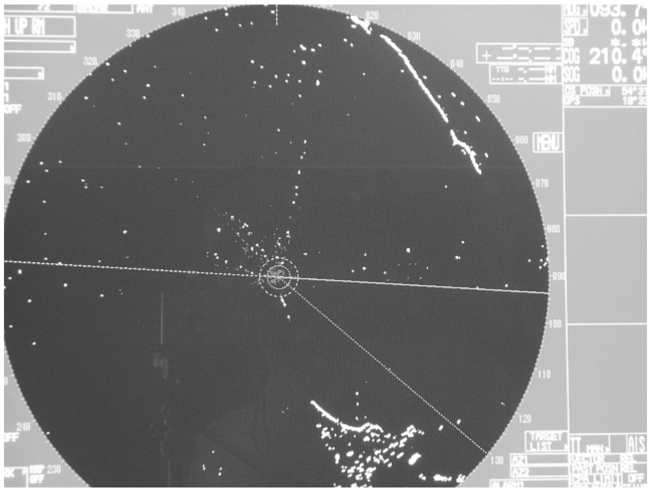

Figure 4. Circle-shaped interferences suppressed digital algorithm.

3 EXTERNAL INTERFERENCES

In order to limit the influence of other electronic devices working in the same band of frequency FMCW signal should be conditioned. The typical example is a problem with beams of the pulsed radars which appear on the display as a radial row of dots (Fig. 2). High level of such a radar signal masks the nearby echoes. Data conditioning algorithm limits the level of time-domain data to average signal level in the sweep. It results in limiting unwanted products after FFT processing. Second source of external interferences are reflections coming from nearby buildings and sea clutter. Distinguishing sea clutter with real objects is often problematic. In any case some kind of filtering is needed [1]. Possible solution is a filter based on clutter-map implemented as a type of CFAR [2].

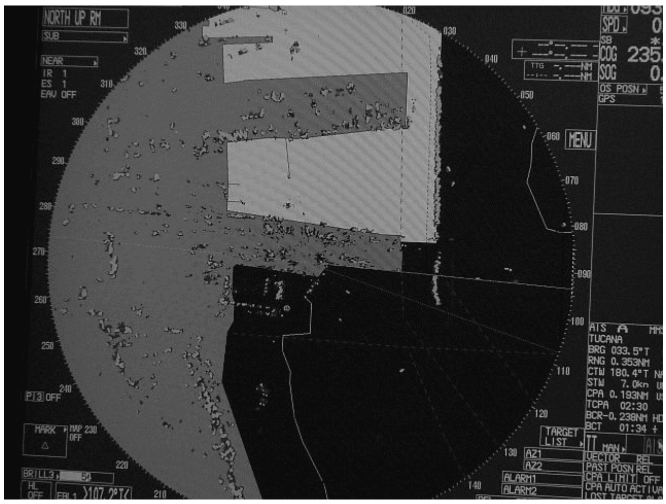

Figure 5. Gdynia harbor 0.25Nm range GO-CFAR

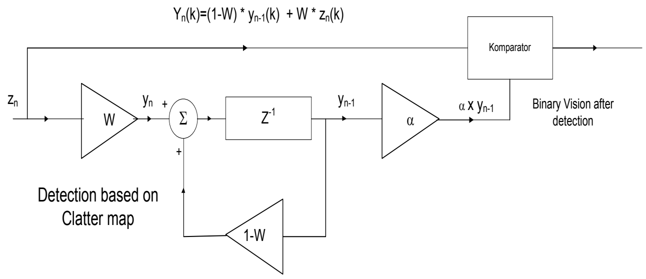

Figure 6. Clutter map algorithm concept

Clutter-map estimate caries information about the past and present values of particular range-angular cell. The more up-to-date the data is, the greater contribution in estimate it has. The state of the estimate is continuous up-dated in RAM memory. The value of the estimate can be written as:

$Y_n(k)=(1-W) * y_{n-1}(k) + W * Z_n(k)$

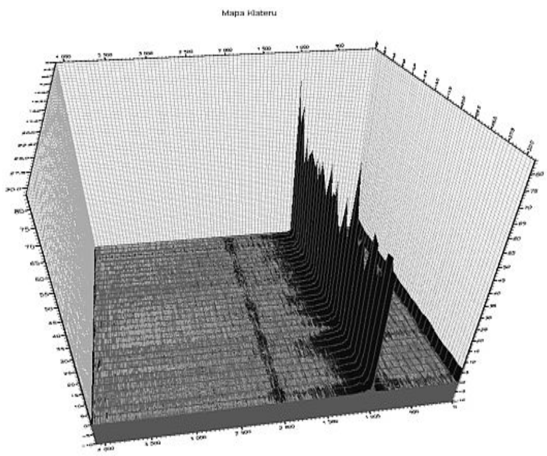

Figure 7. Clutter-map estimate of 32 sweeps in a row (Y-axis).

To store the estimate N x M x 2 bytes of RAM are used (N-number of range cells, M- number of sweeps per antenna rotation). For N=4096 and 3000 sweeps per rotation 24 MB of RAM is occupied only by clutter-map estimate. The need to access to a large and relatively slow external SDRAM, which deteriorates processing speed is the main disadvantage of such kind of CFAR.

Detection probability is given by the following expressions [4]:

$$P_D = \frac{1}{\prod_{m=0}^{M}[1+\alpha_D W(1-W)^m]}$$

$$\alpha_D = \frac{\alpha}{1+\overline{SNR}}$$

$$M \to \infty$$

The W and α coefficients should be optimized in order to achieve desired probability of detection for maneuvering objects.

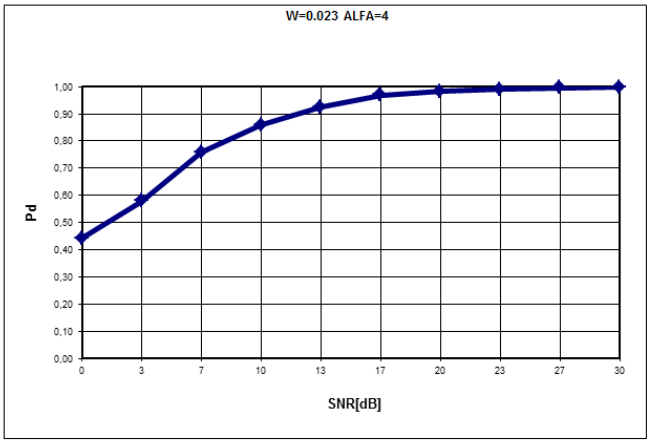

Figure 8. Probability of detection diagram.

W=0.023, K=4.

There are a few characteristic effects of clutter-map algorithm. Any fixed echoes coming from nearby buildings, boardwalks and buoys disappear. In some applications radar echoes of such objects are not needed. Moreover, they are still visible on electronic chart. Sea clutter is suppressed by such kind of detector as well. Figure 5 shows the radar display of Gdynia harbor obtained using GO (Greatest Of)-CFAR type. There are many items redundant including unwanted echoes from nearby port facilities and from the coast line. Results of the detection based on clutter-map are shown in the figure 9. Only maneuvering objects are still visible. Such kind of data processing gives excellent detection performance in case when a small object is moving along boardwalks or quay. In the classical CFAR such object would be overwhelmed by the strong echoes from large fixed objects. Another advantage of clutter-map in context of the tracking system, is a limitation of data stream, because plots which are sent from extractor are preliminary filtered.

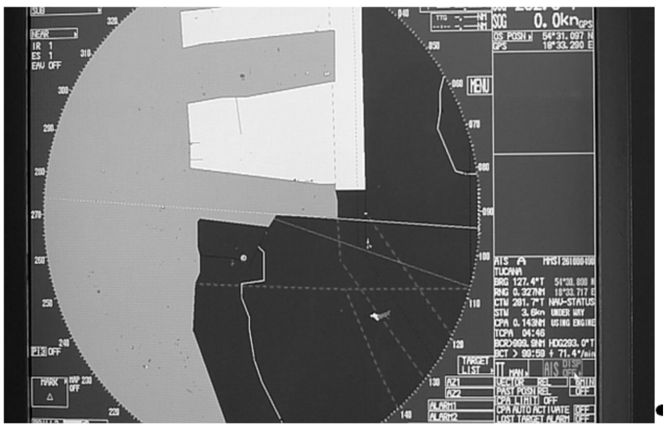

Figure 9. Gdynia harbor 0.25Nm range CFAR based on clutter-map.

4 CONCLUSIONS

In this paper an approach to improve FMCW radar detection was presented. All measures of suppressing internal and external interferences were based on different kind of CFAR. It was shown how to eliminate false, artificial echoes which may mislead the operator or the tracking system. Some advantages of detection based on clutter-map were considered as well.

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