THE SOFTWARE-BASED IMPLEMENTATION OF THE CFAR RECEIVER FOR THE PROCESSING OF THE RADAR SIGNAL

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Summary The performance of a radar receiver is greatly dependent on the presence of noise. The receiver should achieve the constant false alarm rate (CFAR) and the maximum probability of the target detection. The CFAR receivers are usually used in radar applications for the radar signal processing in case of unknown or time-varying background noise statistics, especially in cases when clutter or jamming signals are above the receiver threshold. CFAR automatically adjusts the threshold to prevent the threshold crossings. The paper deals with a software-based implementation of CFAR. The software-based CFAR processing was tested on various types of processors and processing times were compared. The best results were achieved using the dual-core AMD Athlon64 X2 4800+ using SSE2 instructions for processing.

1. INTRODUCTION

The signal received in a radar signal processor is always accompanied by the noise. The performance of the radar receiver is greatly dependent on the presence of noise, and the receiver is expected to achieve constant false alarm rate (CFAR) and the maximum probability of the target detection. The returns from other targets referred to interfering targets, unwanted echoes (clutter) typically from the ground, sea, rain or other participations, chaff and small objects; interfere with the detection of the desired targets. The distinction between clutter and the target depends on the design of the radar system. For air surveillance radars, ground, rain and weather conditions are clutter sources. For radars in meteorology, weather conditions are regarded as a target, and aircrafts are considered as clutter. On the other hand, ground is considered as a target for a ground mapping radar while weather conditions and aircrafts constitute clutter sources [1, 2].

An important condition of an automatic detection of any process is the achievement of a constant false alarm rate (CFAR) [3]. CFAR in the automatic detection radar systems is an algorithm of the digital signal processing, which provides the detection of targets.

An operator observes a PPI (plan position indicator) display or an A-scope and perceives the echo pulses available from the target by his eye-brain combination. Although an operator in many cases can be as effective as an automatic integrator, the performance is limited by the operator's fatigue and boredom. With an automatic detection by electronic means, the detection decision in not depended on the operator [3]. The automatic detection represents a part of the radar that performs the operations required for the detection decision without an operator intervention. The automatic computer based decision devices can operate with far greater number of targets than an operator can handle. This system compares the output of the digital filter operating in real time with the threshold. Then the system achieves the detection of an object with the constant false alarm rate automatically. The results of threshold tests are registered and processed.

The automatic detection and tracking (ADT) system [1, 3] usually handles many targets. Its role is to determine if clutter or jamming signals above the receiver threshold represent real tracks of a target. If a false alarm will not form a real track, it will be discarded by the tracking computer. However, an automatic system might suffer from the limited capability to react quickly enough. In this case it requires too much time of computer capacity to recognize and to discard false alarms. A large number of real targets, a large number of clutter echoes, interferences, and/or high external noise levels might cause overload of even high-performance computers. Therefore, if ADT is to work properly, it is necessary to prevent clutter and external noise to get the automatic-tracking computer. A successful solution can be accomplished by CFAR [2, 4].

The paper is devoted to the description and improvement of characteristics and parameters of the CFAR receiver. CFAR receivers with 8 and 32 cells in the tapped delay line for constant k = 9 are simulated. The performance and properties of CFAR receiver based on XILINX and a software-based solution are compared. The software-based CFAR receivers with various types of processors are simulated and performance times are compared.

2. CELL-AVERAGING CFAR

2.1. Design background

The mostly used form of CFAR is the cell-averaging CFAR (CA-CFAR) that is shown in Fig 1. It uses an adaptive threshold whose level is determined by the clutter and/or noise in the vicinity of the radar echo. Two tapped delay lines sample echo signals from the environment in a number of reference cells located on both sides of the test cell (the range cell of interest). The spacing between reference cells is equal to the radar range resolution (usually the pulse width). The output of the test cell is the radar video output, which is compared to the adaptive threshold derived from the sum of the outputs of the tapped delay lines defining the reference cells. This sum, therefore, represents the radar environment to either side of the test cell. It changes as the radar environment changes and as the pulse travels out in time.

In the vicinity of the test cell there are two guard cells G (Fig.1). The advantage of this set-up is the search of group targets [5–7]. The implementation of guard cells is of vital importance if the size of the tapped delay line (left or right) is smaller than 8 cells. In the tapped delay line with a reduced number of cells, an object may appear in two cells and it may increase the threshold in any cell. The implementation of guard cells increases the CFAR sensitivity.

The constant k determines the ratio between the values of the test cell and the range of surroundings for the comparator in Fig.1.

The selection logic depends on the method of the digital detection of an object. That can be CA-CFAR (Cell Averaging CFAR, selection logic equals U+V), GO-CFAR (Greatest-of-selection logic CFAR; max [U+V]), SO-CFAR (Smallest-of-selection logic CFAR; min [U+V]) and OS-CFAR (Ordered Statistic CFAR). The principle of OS-CFAR is the assignation of the threshold value based on the amplitude ordering [7, 8].

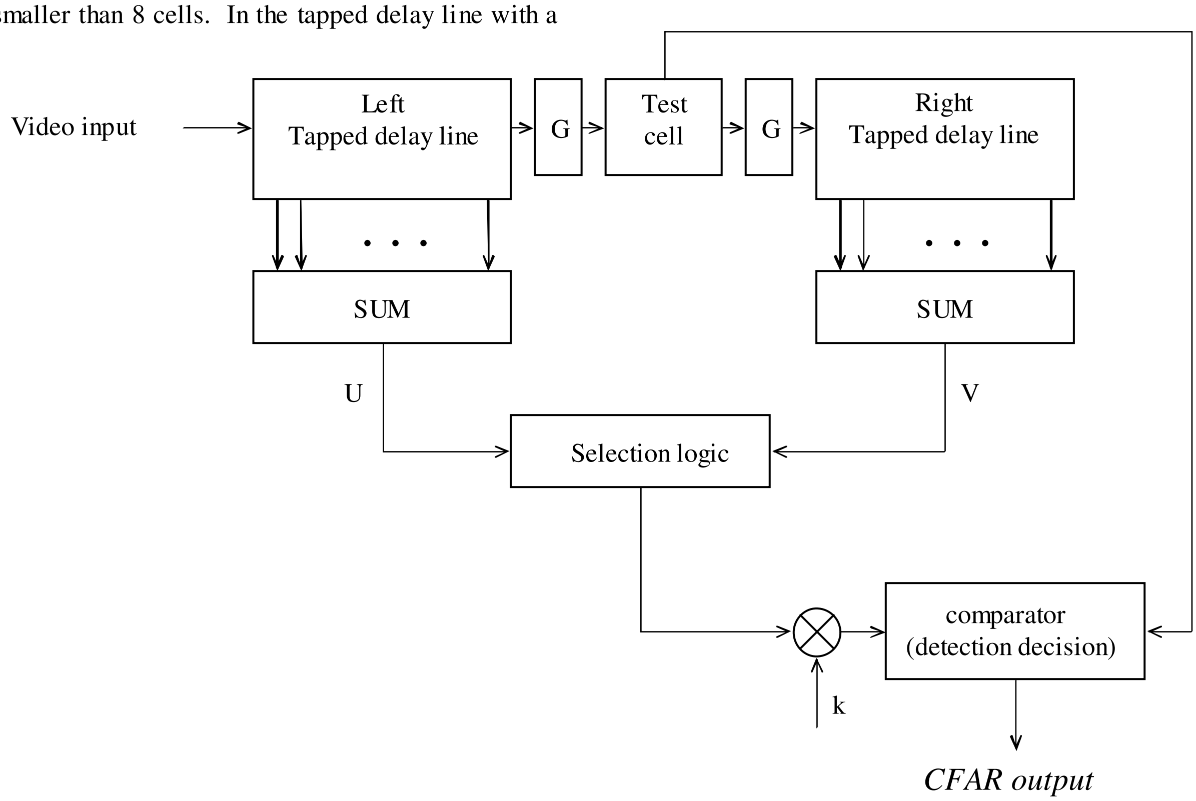

Fig. 1. CFAR receiver

CFAR receivers increase the signal to noise ratio and select echoes in the signal, which are apparently higher than echoes from the nearest vicinity. CFAR receivers detect objects without deciding if objects are moving or stationary. The further radar signal processing divides the objects in the moving and stationary categories.

2.2. CFAR simulations

In Fig. 2 and Fig. 3 the performances of CFAR receivers in the automatic detection of objects are represented. The simulation is implemented in the specific simulated data from the hypothetical radar for one rotation period with the GO-CFAR method. We simulated the CFAR performance with the constant $k = 0.9$ and with 8 and 32 cells in the tapped delay line.

The results of the simulation show, that for the greater number of cells in the tapped delay line the values of the adaptive threshold in the vicinity of the test cell is low (Fig. 3). The benefit is the detection of more targets in the vicinity of each other. However, in this case a missed detection can occur because of higher threshold in vicinity of ground objects (Fig. 3 the distance of 300). When the tapped delay line has 8 cells, the target can be allocated in more than one cell which results in increasing values of the threshold. In case of 32 cells in the tapped delay line, the threshold in the vicinity of the test cell is lower than in case of 8 cells. Besides this, the numerical simulations show that the greater number of cells increases the signal to noise ratio.

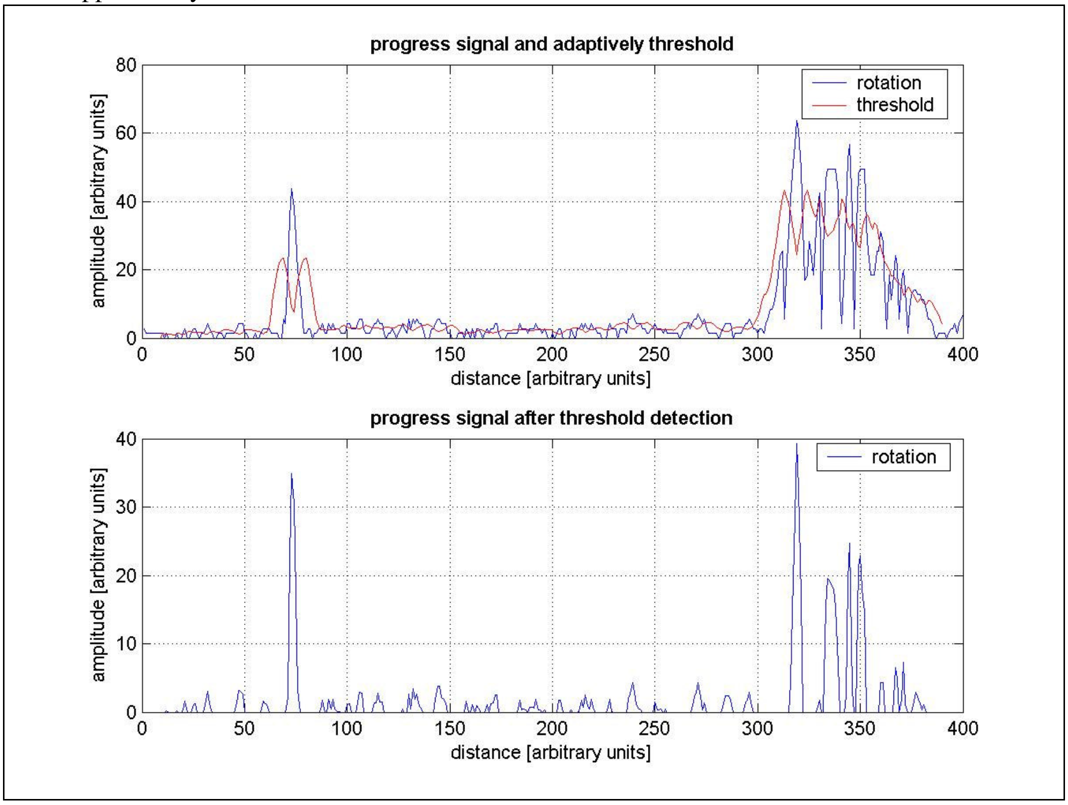

Fig. 2. CFAR receiver for 8 cells in the tapped delay line

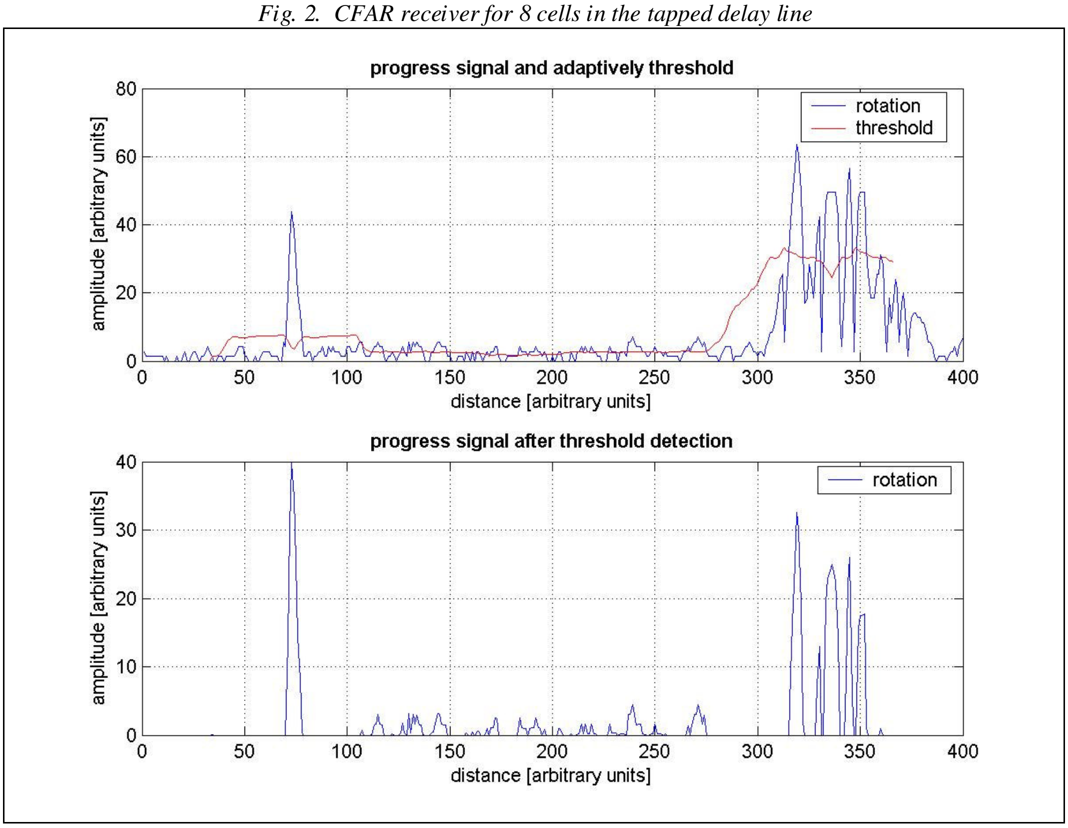

Fig. 3.. CFAR receiver for 32 cells in the tapped delay line

3. THE SOFTWARE-BASED IMPLEMENTATION

As it was mentioned there are various designs of CFAR receivers and each of them has its own benefits or disadvantages. For example, OS-CFAR demands memories with great capacity due to statistics sorting and in this case it is more suitable to use software-based designs.

In Table 1 the performance and properties of CFAR receiver based on XILINX and on a software-based solution are compared. Besides the compared items, we should notice that the XILINX version is more time-consumig than the software-based receiver.

Table 1. Comparison of XILINX and sofware

	XILINX	*software*
Demands	simulator logic analyser or oscilloscope testing software	programming backround compiler debugger
Costs	1000 USD	majority of programs is free
Mathematics	10-bit form	More-bit form, float

In general the software-based solution offers cost savings.

The velocity and the efficiency of the operation processing is important for the achievement of the better detection accuracy. The aim is to decrease the processing time of CFAR receiver and at the same time to increase the probability of the detection. Software-based solutions offer better variability. We tested a software-based CFAR receiver with several kinds of processors. The processing times of the signal corresponding to one radar rotation with 2700 samples were compared for all three tested processors. In our tests of the times of software processing, MMX and SSE instructions were used for the comparison. MMX is an instruction that processes together 64 bits (4 x 16-bit integer data). SSE instruction used by multi-core processors handles together 128 bits (8 x 16-bit integer data or 4 x 32-bit float data). The results are shown in Table 2.

Table 2. The times of software processing

Processor	*Processing time of CFAR receiver*
Intel Celeron 1200MHz (MMX instruction)	92 μs
AMD Athlon64 3200+ (SSE2 instruction)	12 μs
AMD Athlon64 X2 4800+ (SSE2 instruction)	6,6 μs

It is evident that the shortest time was achieved using dual-core processor AMD Athlon64 X2 4800+. As it is well-known, multi-core processors in general offer higher performance and quicker data processing due to parallel processing [9]. It follows from our results that the same holds true also for the area of radar signal evaluation.

4. CONCLUSIONS

In this work, we considered the improvement possibilities of the CFAR receiver performance and its implementation in the radar receiver. The change of the parameters depends on the surroundings where the radar operates. The simulations shown, that the change of parameters depends on the balance between the detection decision and the missed detection. The software-based solution gives the advantage of the simplicity of the change of the parameters. The times of the software processing of the CFAR receiver signal descend when multi-core processors are applied in comparison with the onecore processor. New today's processor technologies – 64-bit address memory, new multimedia instructions, hyperthreading, safety functions, but above all multi-core are expected to help also in improving the radar signal processing by the CFAR receiver.

Acknowledgement

The author would like to acknowledge J. Kindernay and E. Kupco for technical assistance.

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