CW and FM-CW radar adaptation for vehicle technology

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Part 2

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5 Introduction

In the first part of the article we are concerned with the theory of the FM-CW radars. Then we discuss the exact processing of more objects. We review the operational disciplin of security radars which use the FFT, the DFT and the CFAR.

6 The sign processing of more objects [3,5,2,4]

In the figure number 14 the sign of the modulator $f(t)$ and the difference between the frequency of the diffused and the reflected signs which are subject to speed, can be seen.

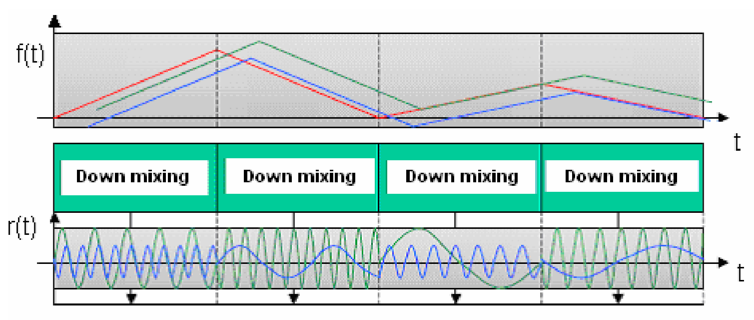

Figure 14.

Then comes the digital processing of the signs, the first step of which is the spectral analysis. The several sign of the objects are interspersed, these must be separated into components of frequency, that is a superposed sign series is taken apart into their components. To take then apart we use the algorithm of Fast Fourier Transformation (FFT). [18, 19] The linear transformation is favoured in the case of processing more objects, because its attribution and behaviour don't depend on the number of objects. The FFT count is used in simple, not complex counts.

Using the Discrete Fourier Transformation, its value at real outgoing signs is not suggestive. However the outgoing sign is always limited in period (T chirp), so its frequency definition ($1/T$ chirp) is also limited. The limited outgoing sign is called windowed. The FFT is a more quicker method than the DFT. At the incoming time it means a rectangular cell where we place a frequency in the best possible way. Using the FFT the partion of frequency place happens in cells. During the transformation the efficiencies are added within all the frequency compartments. The determination of the object happens by comparing the size of all of the signs using the Constant False Rate algorithm. Right now we use the OS-CFAR (a version of the CFAR algorithm), its scheme can be seen in figure number 15.

After identifying the object of the frequency of the reflected sign is approximately known from the first FFT cell in figure nr. 16. We compare the efficiency values of the two nearby cells to get the relevant frequency $S(f_0)$ of the maximum sized cell efficiency. We use the following algorithm:

$$f = \frac{f_{-1}S(f_{-1}) + f_0 S(f_0) + f_1 S(f_1)}{S(f_{-1}) + S(f_0) + S(f_1)}$$

f_{-1} = frequency of lower bin
f_1 = frequency of upper bin

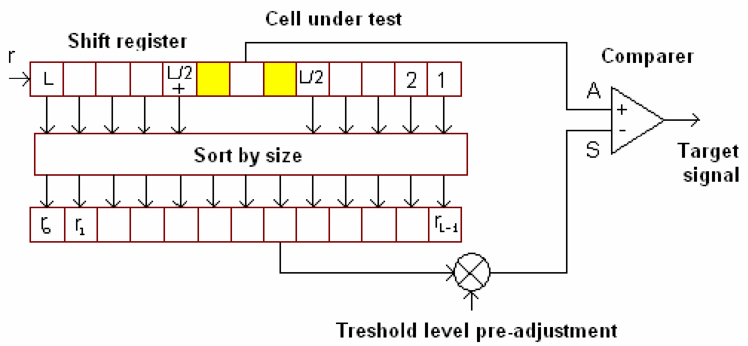

Figure 15.

If we need a better precision the amplitude in the cells must meet the following conditions:

$$x_1 \leq x_2 \leq \cdots \leq x_N,$$

$$Z = x_k.$$

In the case of the correct estimate method:

$$P_{X_k} = p_k(x) = k(N)\left[1 - P_x(x)\right]^{N-k}\left[P_x(x)\right]^{k-1} p_x(x).$$

Accordingly using the statistic evaluation it gives the variation of exponential signs:

$$P_{X_k} = p_k(x)\frac{k}{\mu}(N)\left(e^{-x/\mu}\right)^{N-k+1}\left(1 - e^{-x/\mu}\right)^{k-1}.$$

Lastly the probability of false alerting can be shown:

$$P_h = k\binom{N}{k}\frac{(k-1)!(T_{OS} + N - k)!}{(T_{OS} + N)!}.$$

The factor measuring the results depends on Ǐ completely. Nadav Levanon [10, 12] used the OS-CFAR for the first time for the Weibull coefficiented sign series and then he defined the results analytically. Blake analyzed the OS-CFAR for interferences and Haykin extended the possibilities of the OS-CFAR to the vehicle safety radars that oprate on 77 GHz frequency.

Then the disconnected frequencies and intersection analysis are estimated. The recever's block scheme can be seen in the figure number 16.

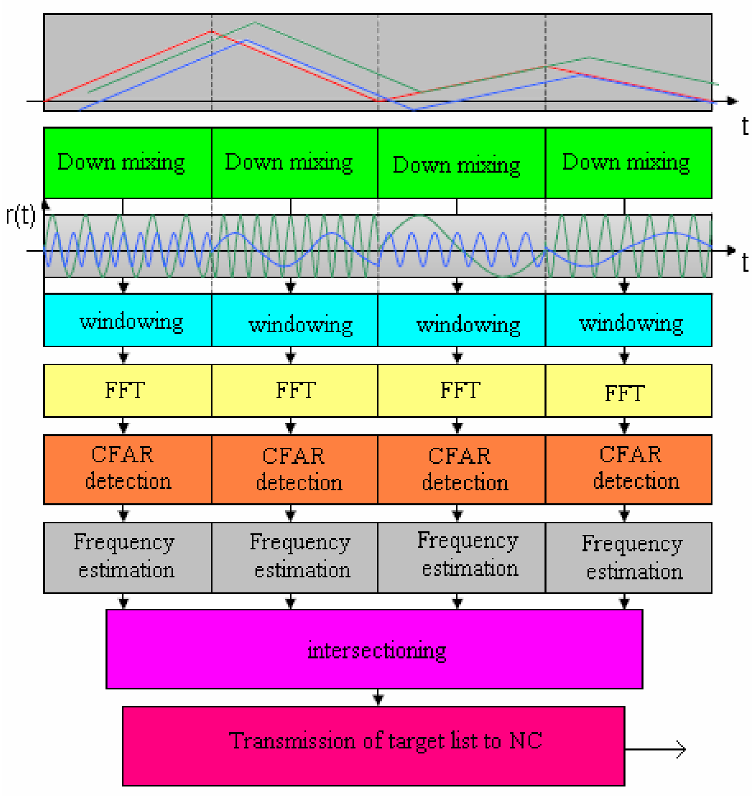

Figure 16

7 CFAR - Constant False Alarm Rate [11, 12, 17]

The major task of this device is to observe the objectives (cars) and to estimate the parameters, too. To observe an objective could be easy, if we knew the background noise and many other noises. In this case the refleced sign could be compared with a concrete fixed limit value. If the reflected sign is bigger than the limit, the objective sign could rise from the noises. In the case of real practice there is more disturbance and noise which variets in time, place and intensity. They claim the same processing. The used technology is called the adaptive method when the comparing is not used with fixed limits, but changings limits. [11, 12]

The processing of radar signs, during the Doppler processing of the sign compression there could be disturbances and vestiges of disturbances. Rain, snow and industrial noises offen cause such noises. These disturbances could be avoided with big probability value and the Constant False Alarm Rate is almost permanent, if we give a fixed limit value. It means there's a big expectation of the CFAR to supply the norms of the distance definition, moreover the limit value must follow the value of the the background noise amplitud in the quickest way possible.

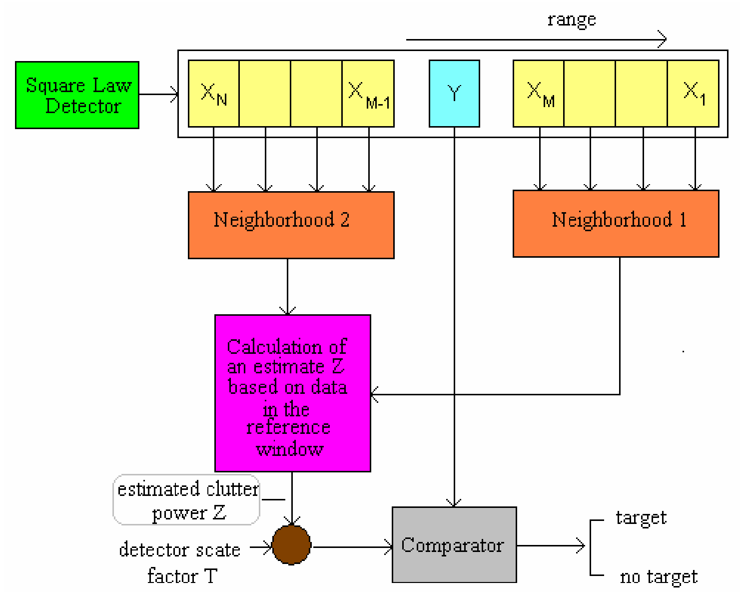

Figure 17

Figure number 17 shows the general synthesis of CFAR, while estimating every data it uses a window, cell the number of which depends on number of background noises. Their number is different considering vehicle traffic, air traffic and ship traffic. For example, air traffic uses approximately $16 \ldots 32$ cells. In the case of cars, is needed less. On a first approximation let's assum that within the line cells of the statistic model the regressors have an exponential character. Non linear chirp are often exponential. In this case consistence function is:

$$f_0(x) = \frac{1}{\mu} \exp\left(-\frac{x}{\mu}\right)\Big|_{X \geq 0}.$$

The probability of false alarm rate depends on the parameters of disturbances and noises, moreover $\sigma^2 = \mu^2$, then the probability of false alarm is:

$$P_h = \int_S^\infty f(x)dx,$$

$$S = T \cdot \mu.$$

If the amplitude of the object doesn't fluctnate, the consistence of the amplitude could be written with the help of the Rician formula.

$$f_1(x) = \begin{cases} \frac{x}{\sigma_0^2} \exp\left(-\frac{x^2+c^2}{2\sigma_0^2}\right) J_0\left(-\frac{xc}{2\sigma_0^2}\right) & \text{if} \quad x \geq 0 \\ 0 & \text{in every other case} \end{cases}$$

The probability of recognition of the objective signs in the case of not homogeneous fluctuating noises is:

$$P_d = \int_S^\infty f_1(x)dx,$$

Up to date CFAR Technology identifies the background disturbances and these are analyzed with the help of different CFAR processes. We do not know the starting level of average disturbances and noise, that is why we must estimate it everytime. The recognizing limit level is estimated with local parameters, but result of the CFAR method's could be different from the value of the statistical evaluation. In the development of CFAR methods, Neumann and Pearson played an important role.

János Neumann's original thesis: Distribution of the ratio of the mean-square successive difference to the varience.

Every CFAR methods can be used in radar technology many times.

The methods include the clean noises, the local disturbances, one target in the noise and two objects. Below we introduce the types of the CFAR algorythms.

7.1 CAGO-CFAR (Cell Average Greates of- CFAR)

The circuit includes a stepping register, which has two sub registers which have N archivers. The two sub registers are connected with Cell Under Test (CUT). Both sub registers have their own summators. From the two values we normalize the bigger one with the cell number of the sub register division:

$$Z = \max\left[\left(\frac{2}{L}\sum_{i=1}^{\frac{L}{2}} x_i\right)\cdot\left(\frac{2}{L}\right)\sum_{i=\frac{L}{2}+1}^{L} x_i\right].$$

7.2 CA-FAR

In the CAGO-CFAR method if we change the summarizing for the MAX process, we talk about CA-CFAR Cell Averaging.

In this method the signs of disturbances and noise consist of statistically substantive and equally dealed exponential distribution accidentally changing measured by a detector. The optimal sign processing uses more arithmetic signs by the cells using the following expression.

$$Z = \left[\frac{1}{L}\sum_{i=1}^{L} x_i\right]$$

The amplitude of the sign means the arithmetical average which in practice can be well estimated. Its disadvantage is that in the case of two objects both signs can not always be detected moreover it has the most false alert. Usually it is used only for homogeneus noises.

7.3 CAOS-CFAR

Combining CAGO-CFAR and OS-CFAR the following versions are possible.

8 CHAS-CFAR- Cell-Averaging Statistic Hofele [20]

The CHAS-CFAR includes a changeable register that has sub registers with N cells, and it has its own summing. The advantage of this processing is that it avoids alternate covering and the aggregation of objects. Using the CASH-CFAR the special maximum-minimum round good attribution: of is that it leaves the flustered objectives in for eg. rainy areas. Moreover the limit value follows the changing distributions with big steps, practically whitout time delay.

9 MAMIS-CFAR

The MAMIS-CFAR (Minimum-Maximum Statistic) is almost the same as the CASH-CFAR, but there are only some modifications in the circuit.

10 Summary

In the second part we'll talk about the more objective methods using the Fast Fourier Transformation and the method of the limit value configuration. As a continuation we'll introduce the different compression methods using the Kalman-filter and Bakar-codes.

References

[1] Dr. Tamási Ferenc: Rádiólokátortechnika Zrínyi Katonai Kiadó-Műszaki Kiadó, 1968 [page 14. . . 20]

[2] Dr. Oláh Ferenc: Válogatott fejezetek a navigációs berendezésekhez. Tankönyvkiadó, Budapest, 1992. [page 412. . . 418]

[3] S. Slater, (Jaguár), A. Sjögren (Volvo), A. Beutner (Volvo), W. Bullinger (DC), K. Möhle (DC), D. Maier. (BMW), A. Saroldi (CRF), H. Rohling (TUHH), U. Lübbert (TUHH) M. Schiementz (TUHH), A. Garrod (RMR), B. Rickett (RMR), D. Pycock (Uni Bham) E. Hoare (Uni Bham), F. Castanie (INPT) R. Doerfler (Siemens VDO), M. Brandt (Siemens VDO), A Hoess (Siemens VDO): MULTIFUNTCIONAL AUTOMOTIVE RADAR NETWORK (RadarNet). Deliverable D40 Finál Report. 2004. [page 30…36]

[4] Lecture Script: Radar System Engineering Edition WS 2005/2006 [page 19…21, 43…46]

[5] Skolnik, M: Introduction to Radar Systems McGraw Hill Text. 2000. [page 3…5]

[6] Detlefsen J: Radartechnik, Springer-Verlag, 1989. [page 28…47]

[7] R, Mende: Radarsysteme zur automatischen Abstandsregelung in Automobilen Dissertation. 1999. [page 48…76]

[8] Stove, A. G: Linear FMCW Radar Techniques IEE Proceedinds-F. 1992 No. 5.

[9] H. Rohling: Some Radar Topics. Waveform Design Range CFAR and Target Recognition [page 19…28]. 2005

[10] Levanon, N. : Detection loss due to interfering targets in ordered statistic CFAR. [page 678…681] IEEE Transactions on AES. 11/1988

[11] Di Vito, A. - Galati, G. - Mura, R. : Analysis and comparison oftwo order statistic CFAR system. [page 109…115] IEE Proceedings 4/1994,

[12] Levanon, N. -Shor, M. : Order statistic CFAR for Weibull background. IEE Proceedings. 6/1990. [page 157…162]

[13] Blake, S. : OS -CFAR theory for multiple targets and nonuniform clutter. IEEE Transactions on AES. 11/1988. [page 785…790]

[14] D. Oprisan and H. Rohling: Tracking system for Automotive Radar Networks. IEE Radar 2002.

[15] M. Ezekiel - K.Fox: Korreláció és regresszió analízis. [377] Közgazdasági és Jogi könyvkiadó. Budapest. 1970.

[16] Dipl.-Ing. Yu Wang: Analyse von Telemetriesignalen und Radar - Rückstreusignalen zur Rekonstruktion von Bahnstrorungen interplanetarer Raumsonden am Beispiel der simulierten Abstiegsdynamik der Huygens-Sonde. Bochum. 2004. [page 51…57]

[17] A. Mende,: Radarsysteme zur automatischen Abstrandsregelung in Automobilen Dissertation. 1999. [page 48…76]

[18] http://itl7. elte.hu/html/jelfel/node32.htm [1]

[19] http://itl7. elte.hu/html/jelfel/node33.htm [1]

[20] Florian Fölster: Erfassung ausgedehnter Objekte durch ein Automobil - Radar Dissertation. 2006. [page 32, 147]

[21] F.X. Hofele, CELL Averaging Statistic Hofele (CASH) CFARImpulshöhenanalyse (IHA) und Pulskompressions- - Nebenzipfel - Maske (PNM, Report of Daimler Benz Aerospace AG, Ulm February 11, 1997.