International Journal of Recent Trends in Engineering & Research
ISSN : 2455-1457 Impact Factor : 3.344

Use of Matched Filter to reduce the noise in Radar Pulse Signal

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Abstract- This paper demonstrates the Matched filter which is applied to both Continuous Wave Radar and Pulse Radar signals to reduce the noise. Matched filter has the strong anti-noise ability; it can also achieve accurate pulse compression in a very noisy environment. For removing noise and extracting signal, Matched Filter analysis is one of the most important methods. The de-noising application of the matched filter has been used in spectrum cleaning of the atmospheric radar signals. This paper demonstrates the algorithms of Matched filter that is used in radar signal processing to reduce the noise. The simulation results indicate that Matched filter has strong anti-noise ability for Pulse Radar.
Keywords—Matched filter, de-noising, radar noise, SNR.

I. INTRODUCTION

Weak and noisy signal detection is a basic and important problem in radar systems. Traditionally, signals can be classified as deterministic signals, which waveforms defined precisely for all instants of time and stochastic processes, which is defined by an underlying probability distribution [1]. These two classes are another important class of signals, known as chaotic signals which have very irregular waveform; but are generated by a deterministic mechanism [2]. A chaotic signal share attributes with both deterministic signals and stochastic processes.

Chaos is the very complicated behavior of a low-order dynamical system, because it is both nonlinear and deterministic [1]. It analyzes a strong notion, using the simple deterministic system to illustrate highly irregular fluctuations exhibited by physical phenomena encountered in nature. Recently, some engineering applications of chaos have been reported in literature [3]-[5]. These can be grouped under two broadly defined categories [4]. One group is synthesis of chaotic signals which includes signal masking and spread-spectrum communications. Another is analysis of chaotic signals. It exploits the fact that some physical phenomena allow the use of a chaotic model.

Matched filter [6] is the most significant tools in the field of signal processing. We analyze the technique and show how such an individual can improve the quality of radar-received signals in a noisy environment for both types of radar i.e. Continuous Wave Radar and Pulsed Radar. The problem addressed here concerns the de-noising of the radar received signal immersed in noise. Several simulations have been performed to verify the algorithm for both types of radar.

In Section II, we briefly described about Matched filter and characteristics of Matched filter related to radar noise reduction. Section III, the simulated result. Section IV, finally, we make some conclusions about our comparison related to noise reduction.

II. NOISE REDUCTION BY MATCHED FILTER

A. Matched Filter

Matched filter is not a specific type of filter, but a theoretical frame work. It is an ideal filter that processes a received signal to minimize the effect of noise. Therefore, it optimizes the signal to noise ratio (SNR) of the filtered signal [7].

The radar received signal $r(t)$ contains two components $s_i(t)$ and $n_i(t)$ that represent the certain signal (e.g. targets) and noise respectively i.e. $r(t)=s_i(t)+n_i(t)$. The matched filter $h(t)$ yielding the output $y(t)=s_o(t)+n_o(t)$ is to generate the maximal ratio of $s_o(T)$ and $n_o(T)$ in the sampling values at time T. Where $s_o(t)$, $n_o(t)$ are the outputs of $s_i(t)$ and $n_i(t)$ respectively after the matched filter shown in Fig. 1.
In Fig. 1, $s(t)$ represents the certain signal(e.g. target signal) we have to detect, and $n_i(t)$ represents the additive white Gaussian noise in the system. $s_{io}(t)$ *and* $n(t)$ represent the output of the matched filter by $s_i(t)$ and $n_{io}(t)$. Matched filter maximized the SNR, the ratio of the power of $s(t)$ and power of $n(t)$ according to the Schwartz Inequality.
Here, we suppose that the noise $n_o i_o(t)$ additive white Gaussian noise, whose power spectrum is $N/2$, and the spectrum of the target's signal $s_i(t)$ is [7].

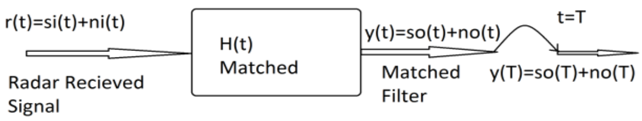

Fig. 1 Matched Filter System

$$F_{s_i}(\omega) = \int_{-\infty}^{+\infty} S_i(t)e^{-j\omega t}\,dt \text{ ------(1)}$$

In above equation it is shown the Fourier Transform of $s(t)$. The output of the matched filter $y(t)$ also contains two components, the target's signal and noise respectively, $y(t)=s_o(t)+n_o(t)$, where

$$S_o(t) = \frac{1}{2\pi}\int_{-\infty}^{+\infty}[H(\omega)F_{S_i}(\omega)]e^{j\omega t}dt \text{ ---(2)}$$

The average power of the noise equals the value of auto-correlation function, which is

$$E[n_o^2(t)] = \frac{1}{2\pi}\frac{N}{2}\int_{-\infty}^{+\infty}|H(\omega)|^2 dt \text{ ------------(3)}$$

Now, according to the definition of the signal-noise ratio (SNR) at the moment T is

$$SNR = \frac{|S_o(t)|^2}{E[n_o^2]} \text{ -----------------------------(4)}$$

$$= \frac{|\frac{1}{2\pi}\int_{-\infty}^{+\infty}[[H(\omega)\,F_{target}(\omega)]e^{j\omega t}]d\omega|^2}{\frac{1}{2\pi}\frac{N}{2}\int_{-\infty}^{+\infty}|H(\omega)|^2\,d\omega}$$

Using the Schwartz Equality, we get

$$|\frac{1}{2\pi}\int_{-\infty}^{+\infty}[[H(\omega)\,F_{target}(\omega)]e^{j\omega t}]d\omega\,|^2$$

$$\leq \frac{1}{4\pi^2} \int_{-\infty}^{+\infty} |H(\omega)|^2 \, d\omega \int_{-\infty}^{+\infty} |F_{target}(\omega)|^2 d\omega$$

$$SNR \leq \frac{\frac{1}{4\pi^2}\int_{-\infty}^{+\infty} |H(\omega)|^2 \, d\omega \int_{-\infty}^{+\infty} |F_{target}(\omega)|^2 d\omega}{\frac{1}{2\pi}\frac{N}{2}\int_{-\infty}^{+\infty} |H(\omega)|^2 \, d\omega} \text{ --------------------(5)}$$

The numerator of the above equation denotes power of the signal according to the Parsifal's Theorem. From equation, the Matched filter maximizes the SNR of the filtered signal and has an impulse response that is a reverse time-shifted version of the input signal. So to obtain the maximum SNR, we need the time delay, *D*. With use of this time delay, *D*, we obtain the output of the cross correlation between transmitted signals and received signals.

B. Cross-Correlation to Find Time Delay D

Correlation is the process to determine degree of 'fit' between two waveforms and to determine the time at which the maximum correlation coefficient or "best fit" occurs [8]. In the radar system, if we correlate between the transmitted signal and the received signal, then we get the time difference between the transmitted and received signals. We consider the transmitted signal to be *x* (*n*), and then the returned signal *r(n)* may be modeled as:

$$r(n) = \alpha x(n - D) + w(n) \text{ -------------(6)}$$

where *w(n)* is assumed to be the additive noise during the transmission, *a* is the attenuation factor, *D* is the delay which is the time taken for the signal to travel from the transmitter to the target and back to the receiver. The cross correlation between the transmitted signal, *x (n)* and the received signal, *r (n)* is [8],

$$C_{xr}(l) = \alpha C_{xx}(l - D) \text{ ----------------(7)}$$

From equation (7), the maximum value of the cross-correlation will occur at *l*=*D*, which is our interest in cross-correlation from which we can get the time delay, *D*. For the multiple targets, we get the multiple number of *D* from equation (7). For example, if there are n targets then we can get n number of delay such as $D_1, D_2, \ldots \ldots \ldots . . D_n$.

C. Matched Filter for Radar

For Pulsed radars, consider pulse width τ_p, τ_k is the time that a target is illuminated by the radars. Thus, we can write *r(t)* as

$$r(t) = V_{rect}[\frac{t-\tau_p}{\tau_k}] \text{ -------------------(8)}$$

From equation (5) and equation (8) we can write the pulse radar as

$$SNR_{pulse} = \frac{P_t G^2 \lambda^2 \sigma \tau_p}{(4\pi)^3 K T_o B F L R^4} \text{ -----------------------(9)}$$

where *Pt* is the peak transmitted power of radar, *G* is the antenna gain, σ is the Radar Cross Section (RCS), *R* is the range which electromagnetic wave transmits, λ is the wavelength, *K*=1.38×10-23J/K is

Boltzmann's constant , $T_0 = 290K$ is the operating temperature of antenna, F is the noise figure of receiver, L denotes as radar losses.
For Continuous Wave Radars, radar equation can be written as .

$$SNR_{CW} = \frac{P_{CW}T_{DWELL}G^2\sigma\lambda^2}{(4\pi)^3KT_oBFLR^4} \text{-------------------------}(10)$$

Where P_{CW} is a continuous wave average transmitted power, T_{DWELL} is a dwell interval.

III. SIMULATION

The de-noising of the received radar signal is simulated in the presence of white Gaussian noise. The effect of signal parameter changes on the algorithm has been investigated. These parameters include the SNR of the signal. The SNR is defined as the ratio of the signal power to the noise power in the entire period.
The receiver receives the return from the targets in the present of AWGN. We recover our transmitted signal from the received signal using the matched filter for both Pulse Radar and Continuous wave Radar. For the Pulse Radar, the recovery signal is almost similar to transmitted signal. But in the case of Continuous Wave Radar, it is almost impossible to understand the shape of the transmitted signal from the recovery signal.
We also apply the wavelet de-noising technique to remove the noise from received signal. This technique overcomes the problem of Continuous Wave Radar.

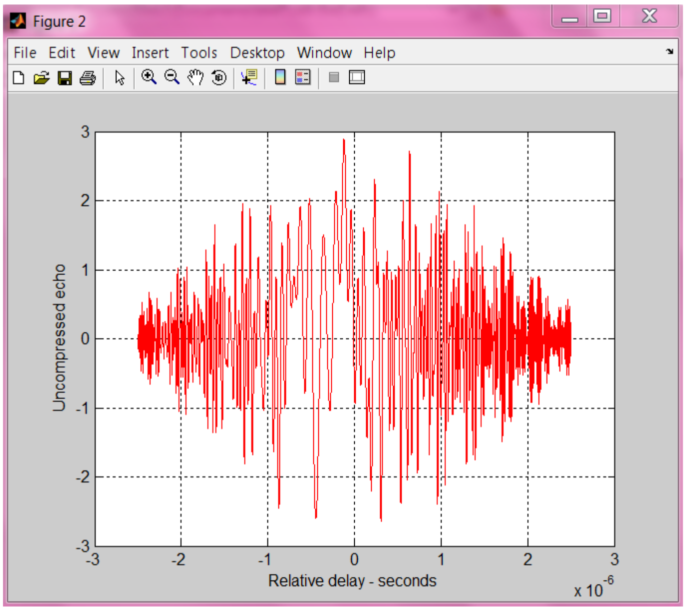

Fig. 2 Uncompressed Received signal (echo + noise)

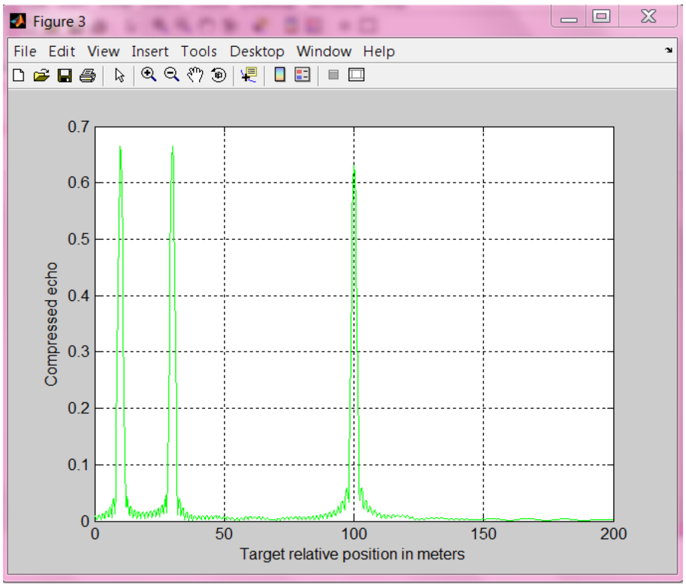

Fig. 3 Recovery signal from received signal by matched filter (echo)

V. CONCLUSIONS

In this paper, the noise reduction of Pulse Radar and Continuous Wave Radar has been studied by matched filter. Matched filter has an advantage in anti-noise ability. A significant reduction in noise is achieved for Pulse Radar by Matched filter, but employing Matched filter for Continuous wave increases the difficulty of detection.

REFERENCES

i. S. Haykin and X. B. Li, “Detection of signals in Chaos,” in *Proc. The IEEE*, 1995, vol. 83, no.1, pp.95-122.

ii. T. S. Parker and L. O. Chua, “Chaos: a tutorial for engineers,” in *Proc. IEEE*, Aug. 1987, vol. 75, no. 8, pp. 982-1008

iii. A. V. Oppenheim, G. W. Womell, S. H. Isabelle, and K. M. Cuomo, “Signal processing in the context of chaotic signals,” in *Proc. ICASSP-92*, vol. 4, pp. 117-120, San Francisco, 1992.

iv. S. Haykin, “Chaotic signal processing: New research directions and novel applications,” presented at IEEE Workshop on SSAP, Victoria, BC, Oct. 1992

v. A. S. Grispino, G. O. Petracca, and A. E. Domínguez, " Comparative analysis of wavelet and EMD in the filtering of radar signal affected by brown noise," *IEEE Latin America Transactions*, vol. 11, no. 1, Feb. 2013.

vi. M. A. Govoni, H. Li, and J. A. Kosinski, "Range-doppler resolution of the linear-fm noise radar waveform," *IEEE Transactions on Aerospace and Electronic Systems*, vol. 49, no.1, pp. 658-664, 2013.

vii. M. S. Islam, H. Han, J. I. Lee, M. G. Jung, and U. Chong, “Small target detection and noise reduction in marine radar systems,” *Sciverse Sciencedirect, IERI procedia*, 2013.

viii. M. S. Islam and U. Chong, “Detection of uncooperative targets using cross-correlation in oceanic environment,” *International Jounrnal of Digital Content Technology and its Applications(JDCTA)*, vol. 7, no. 12, August 2013.