Supplementary Minimization of Clutter Level for Pulsed and MTI Radar

Amer A. Amar
Faculty of Eng. Azzawia
University
Azzawia –Libya

A. Al-Taib Amer
Springfield,USA
Twntieth Century Fox

M. Jalboub
Faculty of Eng. Azzawia
University
Azzawia –Libya

Abstract: In this paper, brief deals with a new initialization technique for digital IIR filters. The technique is suitable for IIR filters processing a finite number of samples in phased array radars. The initialization processor is complex one and utilized the first received sample to force the filter to reach its steady-state value at a single frequency irrespective of the number of processed samples. This is process is reached by initially loading the internal memories of the filter with their steady-state values. If the filter has a zero steady-state response at that particular frequency then this will ensure that the transient frequency responses of the filter will also have a zero response at that frequency. Different processors are derived for filters with real and complex coefficients.

Key words: Digital IIR filters, MTI radar, Complex Coefficient.

I.   Introduction

Surveillance radars with step scanning antenna use MTI processors to distinguish between targets and clutter. The clutter returns may be orders of magnitude larger than those of a target and effectively appear as a large step input to the filter. This can produce such severe ringing in the filter output that the target will be masked until the transient response has settled out. Consequently, for MTI filtering. The internal memories of a digital IIR filter are usually cleared when it is switched on. However, it is possible to initialize the internal memories with values other than zero to improve the transient performance of the IIR filter [1]. This is a useful technique in phased array radars with electronic scanning where the number of samples available for processing is finite. This number is limited by the time during which the target is illuminated by the radar beam which should be kept as small as possible to increase the number of targets under surveillance. Initialization has been used for getting rid of the transient caused by narrow band clutter in IIR filters [1]. This type of initialization is based on the assumption that the clutter level is much higher than the moving target
Level and the input to the clutter rejection filter can be approximated by a step function. If the memories of the IIR filter are initially loaded with their steady-state values for a step input then the transient effects due to the dc component in the clutter can be eliminated completely. This will only be achieved if the filter has a steady-state zero at dc. The zero frequency initialization is suitable for real time processing and requires only the first received sample for calculating the steady-state values of the internal memories. Another technique exists for initializing IIR filters [4], however, it is only useful for batch processing and requires a number of input samples. The IIR filters used in phased array radars for discriminating between moving targets and clutter are high pass filters. Usually, two filters (in-phase and quadrature) are used to avoid blind phases. The analysis of such filters with the zero frequency initialization processors is simplified by using the equivalent filter technique.

II.   Complex Initialization Processor for IIR Filter

Recursive filters have feedback as well as the feed forward coefficients and they can be realized as a cascade of sections as discussed. A second order section with a pair of poles and zeros has following transfer function:

$$H(z) = \frac{a_0 + a_1 z^{-1} + a_2 z^{-2}}{1 - b_1 z^{-1} - b_2 z^{-2}} \tag{1}$$

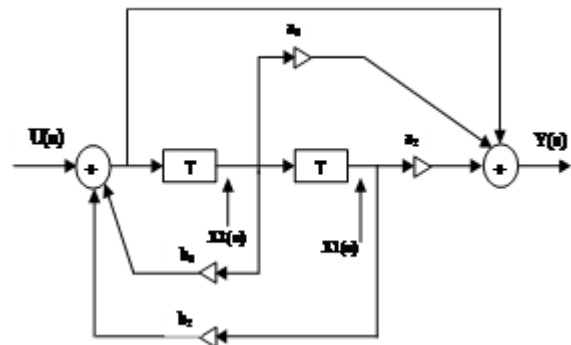This section can be realized as shown in Fig (1).

Figure 1 second order recursive filter

from Fig (1) the internal variables $X1(z)$ and $X2(z)$ are given by:

$$X2(z) = \frac{z^{-1}U(z)}{1 - b_1 z^{-1} - b_2 z^{-2}} \tag{2}$$

$$X1(z) = \frac{z^{-2}U(z)}{1 - b_1 z^{-1} - b_2 z^{-2}} \tag{3}$$

The steady state values of $X1(z)$ and $X2(z)$ should be calculated for both the in-phase and quadrature channels to initialize the filter, so that the output will be zero when the input signals frequency equal f_z.

The steady state values for the in-phase channel are:

$$XI1 = \mathrm{Re}\,al\left[\frac{(UI(1) + jUQ(1)\,)z^{-2}}{1 - b_1 z^{-1} - b_2 z^{-2}}\right] \tag{4}$$

$$XI2 = \mathrm{Re}\,al\left[\frac{(UI(1) + jUQ(1))z^{-2}}{1 - b_1 z^{-1} - b_2 z^{-2}}\right] \tag{5}$$

Where $z = \cos(w) + j\sin(w)$, $w = 2\pi f_z$, $Uq(1)$ and $UI(1)$ are the first input samples.

These two initialization techniques will be the real scenarios when the ground clutter is considered. A program for simulating the operation of the In-phase and Quadrature channels in second order digital IIR filter is used to described these technique.

The steady state values for the quadrature channel are:

$$XQ1 = \mathrm{Im}\,aginary\left[\frac{(UI(1) + jUQ(1))z^{-2}}{1 - b_1 z^{-1} - b_2 z^{-2}}\right] \tag{6}$$

$$XQ1 = \mathrm{Im}\,aginary\left[\frac{(UI(1) + jUQ(1))z^{-1}}{1 - b_1 z^{-1} - b_2 z^{-2}}\right] \tag{7}$$

The initialization processor can be realized as shown in Fig.(2).To Apply initialization the steady state values of the internal memories of the recursive filter will be calculated by the processor from the first received samples. The processor is complex one and it has 8 multipliers 4 adders.

This processor is complex one and calculates the steady-state values of the internal memories from the first received samples of the in-phase and quadrature channels [xi(1) and xq(1)]. The processor has eight
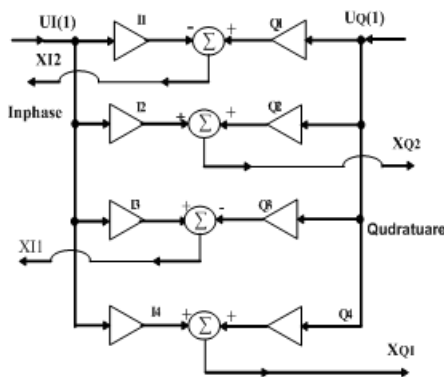

Figure 2 the clutter rejection processor

The moving target is simulated by using the sinusoidal wave

$$X(nT) = A\sin(2\pi f_d kT) \tag{8}$$

Where A is the target amplitude in the test cell, f_d is the target Doppler frequency, k is the number of processed samples and T is the sampling interval.

The clutter is simulated by either a dc signal or very narrow band signal with a Gaussian spectrum given by

$$S(f) = \frac{p_c}{\sqrt{2\pi}\sigma}\exp\left(\frac{-f^2}{2\sigma^2}\right) \tag{9}$$

Where σ is the clutter width (Hz), f is the frequency and p_c, is the clutter level

Figure (3) depicted the output signal of the I-channel after Gaussian clutter introduced on it, without utilized and Figure (4) with utilized the initialization technique in the filter.

Figure (5) depicted the I-channel output signal after the sinusoidal signal, dc and Gaussian clutter introduced on the input and output of the I-channel. Without utilized the initialization technique in the filter and figure (6) illustrated the initialization technique process on the I-channel's output and to improve the transient response of the filter.

In operation, therefore, the first return from each beam position is multiplied by K [1 / (1 - B 1 - B 2)]; For a step input equal in magnitude to an initial radar return signal of *K* this product is then loaded in the filter registers, and the remaining returns from that beam position are processed in the normal manner. This Equation illustrates a problem with the conventional implementation.

The steady state values for the quadrature channel by considering the above factor is recalculated as:

$$XQ1 = \mathrm{Im}\,aginary\left[\frac{(UI(1) + jUQ(1))(z^{-1} - b_1 z^{-1} - b_2 z^{-2})}{1 - b_1 z^{-1} - b_2 z^{-2}}\right] \tag{10}$$

$$XQ1 = \mathrm{Im}\,aginary\left[\frac{(UI(1) + jUQ(1))(z^{-2} - z^{-1})}{1 - b_1 z^{-1} - b_2 z^{-2}}\right] \tag{11}$$

The output of the filter at I-channel will be as :

$$YI(k) = -1 \times (X1I(k+1) - XI(k)) + a_2 \times X2I(k) \tag{12}$$

Where $X1I(k+1)$ is feed-back representation

$$X1I(k+1) = XI(k) + b_1 \times (X1I(k) - XI(k)) + b_2 \times X2I(k) \tag{13}$$

The cascading memory representation instead of writing $X2I(k+1)$

In the analysis

$$X2I(k+1) = X1I(k) - XI(k) \tag{14}$$

The output of the filter at Q-channel will be as:

$$Yq(k) = -1 \times (X1q(k+1) - Xq(k)) + a_2 \times X2q(k) \tag{15}$$

Where $X1q(k+1)$ is feed-back representation?

$$X1q(k+1) = Xq(k) + b_1 \times (X1q(k) - Xq(k)) + b_2 \times X2q(k) \tag{16}$$

The cascading memory representation instead of writing $X2I(k+1)$

In the analysis

$$X2q(k+1) = X1q(k) - Xq(k) \qquad (17)$$

The total output of the filter is the sum of equation 13, 15:

$$Y = \sqrt{(YI(k))^2 + (Yq(k))^2} \qquad (18)$$

The initialization processor can be realized as shown in Fig. (2).To Apply initialization the steady state values of the internal memories of the recursive filter will be calculated by the processor from the first received samples. The processor is complex one and it has 8 multipliers 4 adders

There are two initialization techniques for modified second order recursive filter are used (with and without initialization). These two initialization techniques will be the real scenarios when the ground clutter. A program for simulating the operation of the In-phase and Quadrature channels in second order digital IIR filter
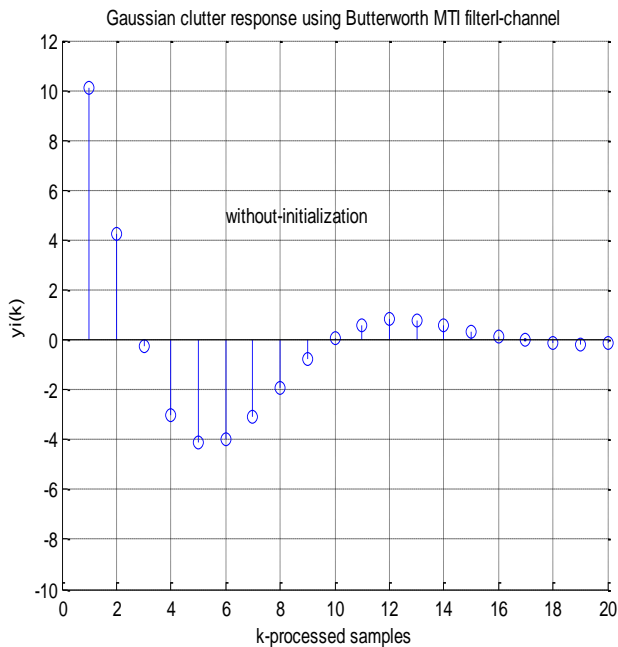
Figure (3) the output signal of the I-channel after Gaussian clutter introduced on it, without utilized the initialization technique in the filter.
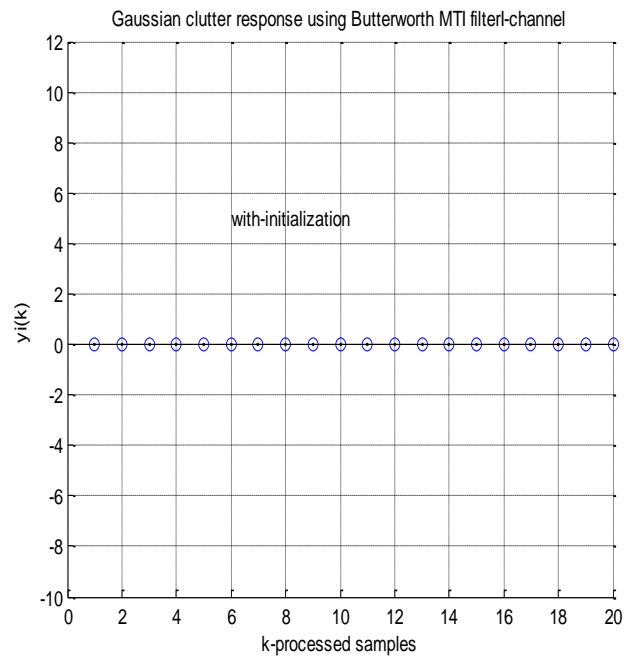
Figure (4) The output signal of the I-channel after Gaussian clutter introduced on it, with utilized the initialization technique in the filter.
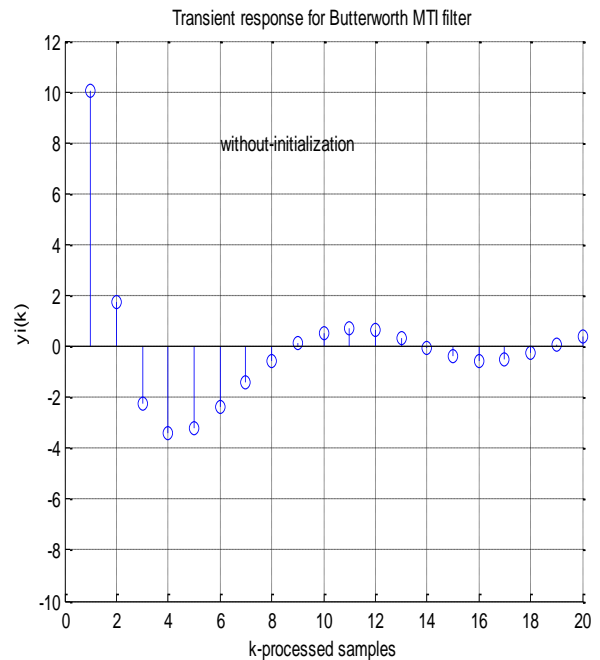
Figure (5) the I-channel output signal after the sinusoidal signal, dc and Gaussian clutter introduced on the input and output of the I-channel. Without utilized the initialization technique in the filter
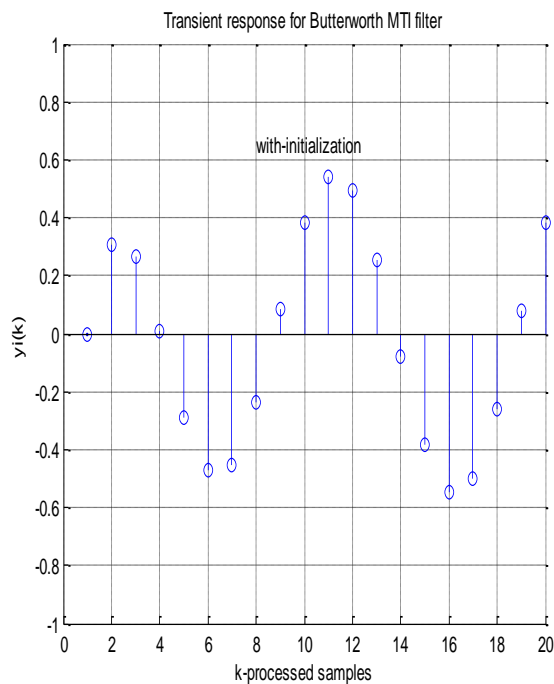
Figure (6)) illustrated   the initialization technique process on the I-channel's output

III.   Conclusions

Initialization processors are derived for different digital filters with both real and complex coefficients. The processor will work in conjugation with digital IIR filters to force the transient frequency responses to have a zero response at a single frequency irrespective of the number of processed samples. These processors will be useful for forcing zero response at a single frequency in phased array radar application where the number of samples available for processing is limited. It should be emphasized here that this technique is useful only for suppressing the transient caused by very narrow bandwidth clutter.

In modified second order recursive filter, the simulations results show that there no significant change in the results in all last applications. In a simple manner, we can say the frequency response of the radar system was improved by using the initialization technique in reception system. Also, the results show that at least 9 samples as a lower limit in order to obtain reasonable response at the steady state. In addition, the application of this technique has a great effect on the transient response of the radar system the transient response of the radar system so that, the radar filter can operate in both steady and transient states. Also, and the desired signal can clear off some clutter and other undesired signals at the radar receiver.
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