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Analysing Chebyshev Filter For Displaying Radar Target Track

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ABSTRACT

Now-a-days, noises are common in communication channels and the recovery of the transmitted signals from the communication path without any noise are considered as one of the difficult tasks. This is accomplished by the denoising techniques that remove noises from a digital signal. The noise in the radar data results in the flutter of the flight target in display screen, which may disturb observer. This paper involves the use of Chebyshev filter for removing the noise from radar signal so that we can receive the clear picture of Radar Signal which is to be displayed. Chebyshev filters are analog or digital filters having steeper roll off and more passband ripple (type 1) and stopband ripple (type 2) than Butterworth filters. Chebyshev filters have the property that they minimize the error between the idealized filter characteristics and the actual over the range of the filter, but with ripples in the passband. By passing the radar signal through the Chebyshev filter noise in radar signal is magnified. The results of MATLAB illustration show that the method has a reliable denoising performance.

KEYWORDS: Radar target track, Chebyshev filter, Butterworth filter, Denoising, Passband, Stopband.

INTRODUCTION

A mass of noise signal is always involved in the radar target track data for the effects of radar clutter, cloud, rain, and radar cross-section (RCS) and so on. The noise disturbs the target identification in the display screen, which causes the illusion the target is fluttering. Many filter techniques to resolve this problem, such as Kalman filtering, least squares procedure, are state estimation methods based on time series, and must consider the target's past state, locus model, and interrelated prior knowledge. But, for the time-varying system, all that information is difficult to acquire, or is inaccuracy [1][2][3], leading to a worse result for the data of detail section[4]. Thereby, with Chebyshev Filter, a method filtering radar target track is proposed in this paper. In the end, the MATLAB simulation shows the method availability.

CHEBYSHEV FILTER DESIGNING

Chebyshev filters are analog or digital filters having steeper roll off and more passband ripple (type 1) and stopband ripple (type 2) than Butterworth filters. Chebyshev filters have the property that they minimize the error between the idealized filter characteristics and the actual over the range of the filter, but with ripples in the passband.

This type of filter is named in honour of Pafnuty Chebyshev because their mathematical characteristics are derived from Chebyshev Polynomials. Because of the passband ripple inherent in Chebyshev filters, filters which have a smoother response in the passband but a more irregular response in the stopband are preferred for some applications.

The gain (or amplitude) response as a function of angular frequency ω of the n^{th} order low pass filter is:

$$G_n(\omega) = |H_n(j\omega)| = \frac{1}{\sqrt{1+\varepsilon^2 T_n^2(\omega/\omega_0)}} \qquad (1)$$

Where ε is the ripple factor, w_0 is the cutoff frequency and T_n is Chebyshev polynomial of the n^{th} order.

The passband exhibits equiripple behavior, with the ripple determined by the ripple factor ε. In the passband, the Chebyshev polynomial alternates between 0 and 1 so the filter gain alternate between maxima at G =1 and minima at $G = 1 / \sqrt{1+\varepsilon^2}$
At the cutoff frequency w_0 the gain again has some value but continues to drop into the stopband as the frequency increases. The order of a Chebyshev filter is equal to the number of reactive components needed to realize the filter using analog electronics. The ripple is often given in dB.

$$\text{Ripple in dB} = 20\log_{10} 1 / \sqrt{1+\varepsilon^2} \qquad (2)$$

An even steeper roll off can be obtained if allowed for ripple in the stopband, by allowing zeroes on the jw axis in the complex plane. This will however result in less suppression in the stopband. The result is called an elliptic filter, also known as Cauer filter. The above expression yields the poles of the gain G .For each complex pole there is another which is the complex conjugate and for each conjugate pair there are two more that are the negatives of the pair. The transfer function must be stable, so that its poles will be those of the gain that have negative real parts and therefore lie in the left half plane of complex frequency space. The transfer function is then given by:

$$H(s) = \frac{1}{2^{n-1}\varepsilon} \prod_{m=1}^{n} \frac{1}{(s - s_{pm})} \qquad (3)$$

There are only those poles with a negative sign in front of the real term in the above equation for the poles.

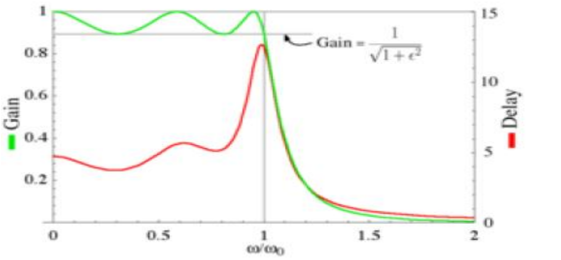

Figure1: Gain and Group Delay of Chebyshev Filter

The group delay is defined as the derivative of the phase with respect to the angular frequency and is measure of the distortion in the signal introduced by phase differences for different frequencies.

$$\zeta_g = -d/d\omega \arg(H(j\omega)) \qquad (4)$$

The gain and the group delay for a fifth order type 1 Chebyshev filter with $\varepsilon = 0.5$ are plotted in the above graph.It can be seen that there are ripples in the gain and the group delay in the passband but not in the stopband.In this paper only type I filter is designed and used[5]. This method has following advantages: (a) the poles of Chebyshev filter lies on an ellipse, which can be easily concluded on looking at the poles formula for both types of filters. (b)The no of poles required in Chebyshev filter are less, as a result order of filter is less. This fact can be used for practical implementation, since the number of components required to construct a filter of same specification can be reduced significantly. (c) The width of the transition band is less in the Chebyshev filter. (d)Also multipliers and adders required in Chebyshev filter are less.

ALGORITHM FOR DESIGNING CHEBYSHEV FILTER

1. It finds the lowpass analog prototype poles, zeros, and gain using the cheb1ap function.
2. It converts the poles, zeros, and gain into state-space form.
3. It transforms the low pass filter into a bandpass, highpass, or bandstop filter with desired cutoff frequencies, using a state-space transformation.
4. For digital filter design, cheby1 uses bilinear to convert the analog filter into a digital filter through a bilinear transformation with frequency prewarping. Careful frequency adjustment guarantees that the analog filters and the digital filters will have the same frequency response magnitude at wp or w_1 and w_2.
5. It converts the state-space filter back to transfer function or zero-pole-gain form, as required.

FILTERING METHOD FOR RADAR TARGET TRACK

Compared with the magnitude of radar data in space-time plane, the power of noise or error is very weak. For example, generally, the order of magnitude of radar data is 10^6 meter in geocentric coordinate system, but the error is only several hundred meter at most. So the data of error must be converted to increase the signal-to-noise ratio (SNR). As being analyzed in frequency-domain, the conversion does not deteriorate the result to acquire the information of error's frequency. The conversion uses the first point in the data as a reference to realize to extract the noise information. As shown in the Equation below:

$$e(t) = x(t) / x(1) - 1 \qquad (5)$$

Then e (t) is the one to be filtered, and the formula is:

$$e'(t) = [b(1) \quad b(2) \quad \cdots \quad b(N+1)] \cdot \begin{bmatrix} e(t) \\ e(t-1) \\ \vdots \\ e(t-N) \end{bmatrix} - [a(1) \quad a(2) \quad \cdots \quad a(N)] \begin{bmatrix} e'(t-1) \\ e'(t-2) \\ \vdots \\ e'(t-N) \end{bmatrix}$$

Where, respectively, a and b are the numerator and the denominator of the filter transfer function which have been z-transformed. And then convert the result back to the original form:

$$x'(t) = (e'(t) + 1)x(1) \qquad (6)$$

x '(t) is the last filtering result [1].

RESULTS AND DISCUSSIONS

Initially a Radar Signal having frequency $4.35 * 10^5$ KHz is taken as shown in figure below:

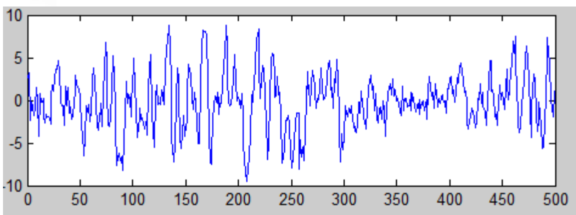

Figure 2: A Radar signal

This radar signal as shown in figure 2 is scaled accordingly for the fixed SNR i.e.10 dB.Thereafter a Gaussian noise is generated and added with the radar signal because addition of noise improves the probability of detecting the signal.

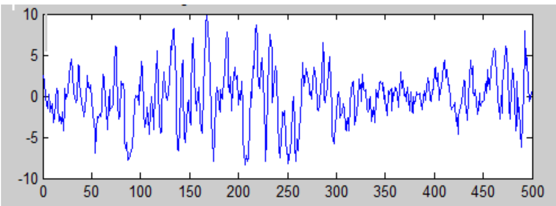

Figure 3: A radar signal with added noise

Figure 3 shows the radar signal with added noise signal giving SNR of 10.0085dB. This produced a radar signal, with Gaussian distribution, zero mean value and a variance of 1.

For the purpose of removing noise from the signal, noisy signal as shown in figure 3 has been passed through the Chebyshev filter.

Parameters used for designing the Chebyshev filter are shown in Table 1.

Table1: Parameters for designing Chebyshev filter

F_s	Sampling Frequency	48000Hz
F_{pass}	Passband Frequency	9600Hz
F_{stop}	Stopband Frequency	12000Hz
A_{pass}	Passband ripple	1dB
A_{stop}	Stopband Attenuation	80dB

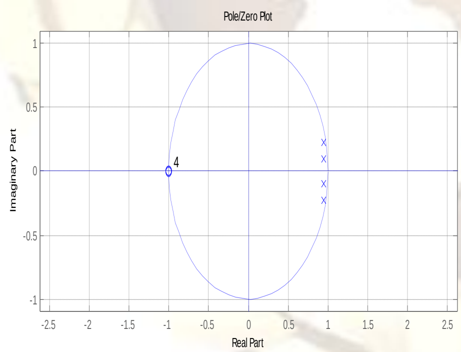

Figure 4: Pole Zero Plot of Chebyshev Filter

Figure above shows the Pole-Zero plot of Chebyshev Filter .Poles of this filter lies on ellipse and minimize the difference between the ideal and actual frequency response over the entire passband by incorporating an equal ripple of R_P dB in the passband.

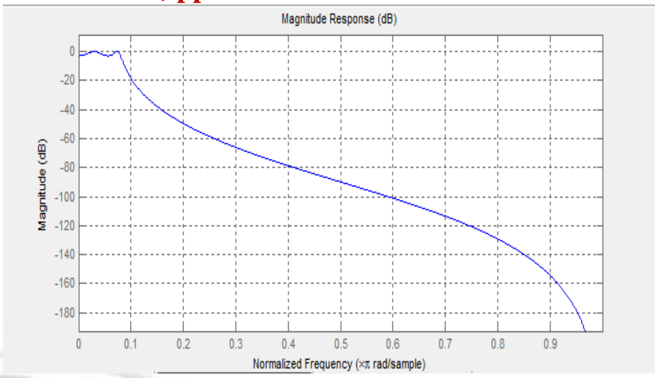

Figure 5: Magnitude Response of Chebyshev Filter

Above figure 5 shows the magnitude response of the Chebyshev filter. From the figure it has been observed that there are ripples in the passband and monotonic characteristic in the stopband .This filter have a smaller transition bandwidth which produces smaller absolute errors, faster execution speeds and steeper roll off rate.

Results obtained after designing the filter are: Order of filter (N)=5,

Normalized Frequency (w_n) = 0.0810Hz,

Filter Coefficients are:

Numerator a = [0.00002919 , 0.0001167, 0.000175,0.0001167,0.00002919].

Denominator (b) = [1 , -3.792 ,5.4556 , -3.5265,.8640].

Thereafter the noisy radar signal as shown in figure 3 is passed through designed Chebyshev Filter.

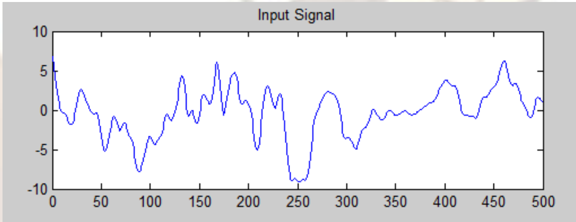

Figure 6: A filtered noisy radar signal

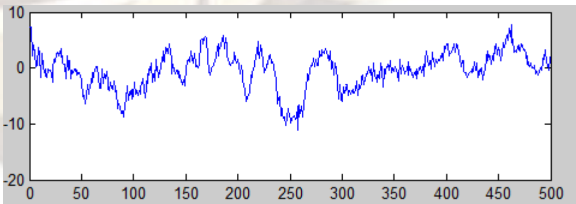

Figure 7: A filtered signal with added noise

Figure 7 shows filtered radar signal with added same Gaussian noise as done in figure 2. Here the noise was added to make comparison between the noisy radar signal and filtered radar signal.SNR measured after adding noise to filtered signal is 10.0615dB which is very high as compared to the SNR (10.0085dB) measured in Figure 3.

CONCLUSIONS

Thus it can be seen that Chebyshev filter is available for radar target track smoothing, if we choose right parameters and transformed the track data. In this research, Chebyshev filter has been developed to smooth radar target track and to observe the flight more factually in control center. This is possible because Chebyshev filters have the property that they minimize the error between the idealized filter characteristic and the actual over the range of the filter, but with ripples in the passband. As the ripple increases (bad), the roll-off becomes sharper (good).

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