The result of IIR Elliptic filter with different depth to process the data Based on MATLAB Software

Jianyu Liu, linlin Dong

Department of Electrical Information Engineering, Northeast Petroleum University, Daqing, 163318, China

Abstract

Ground clutter is part of clutter radar echo signal which is useless, and impact accurate estimates of large data base. According to the time-domain characteristics of ground clutter, this paper research on IIR elliptic filter design methods and the impact of change filter parameters on ground clutter time-domain filter effect. In this paper, we use MATLAB software to design the IIR elliptic filter, and analysis the filter effect of the weather radar signals in the time-domain. From the simulation results we found that the 5th order elliptic IIR with width is 2m/s and the attenuation is 50dB had better balanced effects in the elimination of ground clutter.

Keywords

Ground clutter; Doppler weather radar; Time-domain filter; IIR elliptic filter; MATLAB software

1. Introduction

Ground clutter filter is a high pass filter. Ideally, it can remove the both side of the zero frequency components of the frequency components in the Doppler frequency and leaving the others intact. For clutter filter designs, it is important to recognize that, because any change in the frequency response will make the strength, the Doppler frequency and the frequency spectrum width generate deviations [Liu Taorong et al., 2013].

In this paper we research on time-domain of ground clutter and filter it with different parameter of IIR elliptic filter, in the experiment we found that the fifth-order elliptic IIR with width is 2m/s and the attenuation is 50dB had better balanced effects in the elimination of ground clutter.

2. The Basic Principle of Elliptic Filter to Remove Ground Clutter

Assuming the zero-order self-correlation of filtered weather echo signal is $R(0)$, first order self-correlation is $R(T)$ where T is the pules repetition period. Using PPP (pulse pair processing) method to estimate the spectral parameters (strength, average Doppler frequency and frequency spectral width) as follows:

Strength:

$$R = R(0) \tag{1}$$

Average doppler frequency:

$$\overline{f_d} = \frac{1}{2\pi T}\arctan\frac{I_m[R(T)]}{R_e[R(T)]} \tag{2}$$

Frequency spectral width:

$$\sigma_{fd} = \frac{\sqrt{2}}{2\pi T}\sqrt{1-\frac{|R(T)|}{R(0)}} \tag{3}$$

From the above expression we found these three parameters only depend on the estimate self-correlation function of the weather echo filtered signal. The output PSD (power spectral density)

of linear time-invariant filter $S_y(\omega)$ is related with the frequency response magnitude squared of the filter $|H(\omega)|^2$ and the input power spectral desity $S_x(\omega)$.

$$S_y(\omega) = S_x(\omega)|H(\omega)|^2 \tag{4}$$

According to Parseval theorem, we can see the filtered self-correlation function of the weather echo signals corresponding to the PSD is a Fourier transform pair. Since the phase response of the filter is not included in this transformation, it does not have any effect on the associated filter output signal weather [Cao Longbin et al., 2008].

$$|H_\alpha(j\Omega)|^2 = \frac{1}{1+\varepsilon^2 R_N^2\left(\frac{\Omega}{\Omega_p}\right)} \tag{5}$$

Which $R_N(x)$ is the Jacobi elliptic function, is the relevant parameters of the attenuation in the pass band. The rational function $R_N(\omega)$ is:

When n is an odd number, k=(n-1)/2:

$$R_n(\omega) = \frac{\omega(\omega_1^2-\omega^2)(\omega_2^2-\omega^2)\cdots(\omega_k^2-\omega^2)}{(1-\omega_1^2\omega^2)(1-\omega_2^2\omega^2)\cdots(1-\omega_k^2\omega^2)} \tag{6}$$

When n is an even number, k=n/2:

$$R_n(\omega) = \frac{(\omega_1^2-\omega^2)(\omega_2^2-\omega^2)\cdots(\omega_k^2-\omega^2)}{(1-\omega_1^2\omega^2)(1-\omega_2^2\omega^2)\cdots(1-\omega_k^2\omega^2)} \tag{7}$$

3. IIR Elliptic Filter Parameters Affecting Ground Clutter Filtering

In the experiment, we process and analyze the weather radar signal, by adjusting the parameters of IIR elliptic filters to analyze the impact on the ground clutter time-domain signal. Which stop band bandwidth and attenuation these two parameters can be used to adjust and compare filters Filter can produce a number of products, including PPI plot of reflectivity, Doppler velocity, frequency bandwidth and spectral Doppler spectrum in detail. In order to decrease the impact of the width of the filter, we set to 50dB and the width 1m/s was changed to a width of from 1m/s to 3m/s. For comparison the depth of filter, the width of the filter is limited to 1m/s, and the minimum attenuation from 30dB to 60dB in increments.

3.1 The result of IIR Elliptic filter with different width to process the data

The following are radar data power PPI plot of different widths of the IIR filter after filtering:

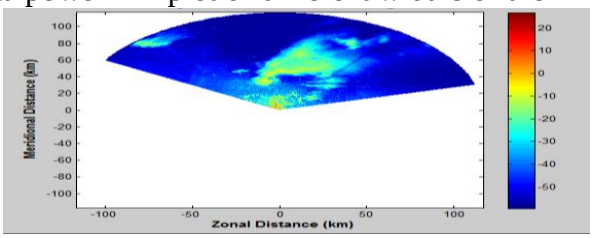

Figure 1. Power PPI plot of original radar data.

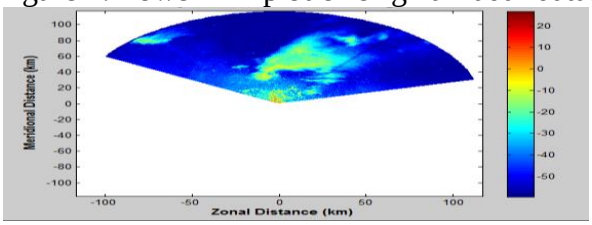

Figure 2. Width of 1m/s filter filtered power PPI plot.

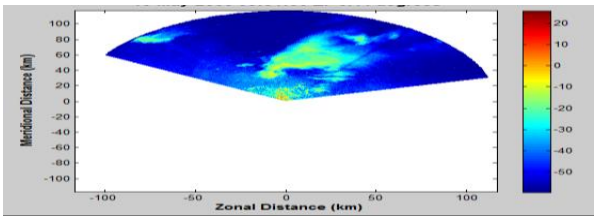

Figure 3. Width of 2m/s filter filtered power PPI plot.

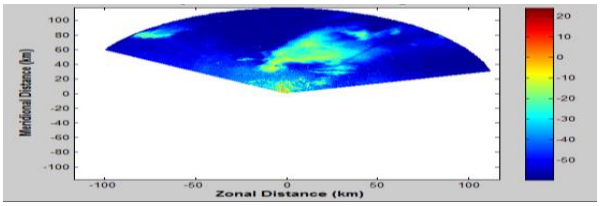

Figure 4. Width of 3m/s filter filtered power PPI plot.

From figure1 to figure 4 are the results of weather radar data which filtered by different width filter, the filtering effect of the filter with different widths are different. Compared with the original power PPI plot, the clutter near the zero Doppler frequency is significantly reduced after filter filters. That because the clutter is mainly near zero Doppler velocity.

3.2 The result of IIR Elliptic filter with different depth to process the data

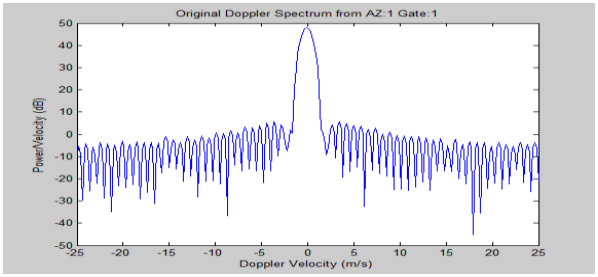

Figure 5. Original doppler spectrum

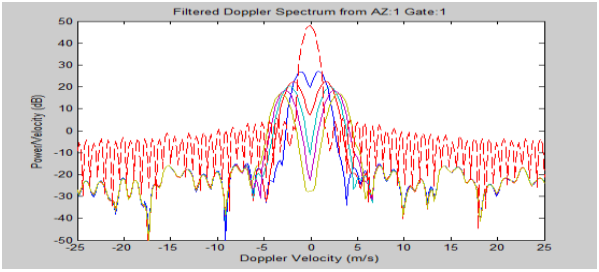

Figure 6. Order is 3,4,5,6,7,8 radar data filtering Doppler filter

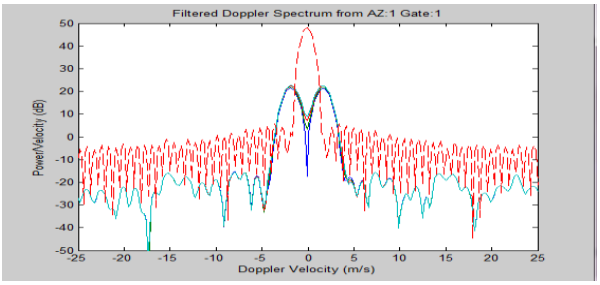

Figure 7. Filtered Doppler singnal by varying Filter Depth

From the figure we can see the details of each filter by Doppler effect on how the clutter signal, where the red line represents the original Doppler spectrum.

Figure 5 shows the width of the filter impact on the Doppler spectrum signals. With the increase of the width of the filter, the maximum attenuation is closer to zero velocity and zero velocity further away from the side lobes. Figure 6-7 shows that the attenuation at different depths have no much affect on Doppler spectrum signals. More likely to be attenuated in the vicinity of zero velocity signal, but with the increase in the minimum attenuation, the sidelobes become stronger. Therefore, in the filter attenuation depth reflection force and not affect very much.

In summary, the filter with attenuation of 50dB and a width of 2m /s have a good balance to filter the clutter, and the 5th order elliptic filter is performed well.

4. Conclusion

In this paper we use MATLAB software to design filters and focus on ground clutter time-domain filtering algorithm research. Clutter generally have a fixed source, and its velocity concentrated around zero Doppler frequency, ground clutter signal bandwidth is very narrow, and the Doppler velocity is zero, if the spectral components concentrated in the zero Doppler frequency, very a large portion of the interference signal will be weakened, we can solve this problem by selecting the appropriate filter. This filter can not only reduce the impact of clutter on the signal, but also can reduce the impact from the weather signal. From the filtering results, it appears that a 2m/s wide filter with a minimum attenuation of 50 dB is a good balance between removing the clutter, and minimizing the affect on the weather spectrum. A 5th order elliptical filter is very to implement on a signal processor in real time for filtering the ground clutter.

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