Disorder system signal spectrum to steal Velocity Range Gate

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ABSTRACT:
In the current paper, linear Digital Radio Frequency Memory (DRFM) is tested to steal Velocity Range Gate for use in electronic war. DRFM output signal steal both of the interval and velocity gate. This output signal spectrum has two important characteristics that, we use them in this paper. First, the central frequency shift is smaller and measurable than the central frequency of input signal. Second, the presence of harmonics with small amplitude being around the central frequency of the data shift. The main factor of the spectrum characteristics is the discrete nature of DRFM. We investigated the development of the states to predict the central frequency shift and harmonics location as a function of radar and DRFM parameters. When electronic war engineers could affect the system performance, these spectrum characteristics are taken attention. The analyzers of signal by these spectrum characteristics can evaluate electronic war systems better.

KEYWORDS: VGP, RGP, VRGP, DRFM.

1. INTRODUCTION

In pulse radar system, the target is searched as automatically and it needs the time of reaching the pulses to the target in searching by the radar. In this technique, the disturbers send a false pulse to the radar as the power of false pulse is higher than the main pulse and it is delay in its sending. As the radar determines the target distance from the pulse return time, this technique causes that the radar images that the target is far from the existing location and exact information don't reach the radar. Radar traces the distance of the required target by initial and secondary gates. When pulse energy is increased in a gate, the radar moves both gates to make energy similar and the target distance is achieved. The disturber by sending a powerful pulse on the main return pulse gets the gates. In other words, the disturber by generating the disturbing pulse with adequate energy, the correct time of returning the main pulse in gates is problematic.

Against the radars doing tracing based on Doppler by CW signals (e.g. Semi-active missile systems), VGPO (Velocity Gate Pull Off) is applied. This method is done as CW method and it has low power peak. In this method, CW signal is used and its power is more than the reflection power of the body of airplane. At first, the required signal in similar Doppler frequency of target reaches the missile receiver and occupies its AGC (Automatic Gain Control), then false signal frequency is changed and shifts velocity gate. It shifts the velocity gate jam to where the generated Doppler lines by clutter exist (low Doppler frequency). In this case, the bended missile goes to the clutter. This method (Automatic Gain Control) is an effective method against tracing radars. This technique is stealing interval gate. Now, this method is the main method being used in self-keeping electronic attack namely against automatic tracing systems. In case of the presence of operator, he is able to diagnose the deception and put the distance gate again on the interval but in case of the lack of presence of the operator, it is adequate to put the interval gate out of the real target place and then by sending false signal dictate it to the radar [1].

In the current study, we investigate the spectrum characteristics of VRGS of a linear DRFM. In the second section, we explained about the properties of DRFM. In the third section, we developed some states to predict the size of central frequency shift and harmonics location. In the fourth section, the simulated results are provided to investigate the existing stages in section 2 and then we deal with the conclusion [1, 2].

2. EXTRACTION OF VGPO SIGNAL SPECTRUM

Assume Doppler pulse radar signal is as following:

$$x(t)=\left(P_\tau(t)\otimes\sum\delta(t-nT_r)\right)e^{j2\pi ft_0} \quad (1)$$

In the following equation, f0 by the following equation is related to the radar sending frequency:

$f_0 = f_r +$ Target Doppler gradient

As it is expected of VRG technique, DRFM output signal is delayed type of input signal as expressed by the following equation [3]:

$$y(t)\approx(P_\tau(t)\otimes\sum_{n=-\infty}^{\infty}\delta(t-nT_r))e^{j2\pi f_0(t-r(t))}e^{j2\pi f_{shift}(t)}$$

(2)

In this equation, r(t) is time delay function showing the delay between receiving and sending signals and $f_{shift}(t)$ is frequency function delay.

If we have:

$$d_{syn}=e^{j2\pi f_0(t-r(t))}e^{j2\pi f_{shift}(t)}=b_{RGPO}(t)\otimes b_{VGPO}(t)$$

(3)

We determine the values here:

$$b_{RGPO}=e^{j2\pi f_0(t-r(t))}$$

$$b_{VGPO}=e^{j2\pi f_{shift}(t)} \quad (4)$$

b_{RGPO} signal frequency spectrum is applied to steal interval gate [3,4]:

$$B_{RGPO}(f)=e^{-j\pi fT_c}\frac{\sin(\pi T_C f)}{\pi T_C f}\sum_{-\infty}^{\infty}\delta(f+\beta f_0 f_c-n_1 f_c)$$

(5)

B_{VGPO} signal frequency spectrum is applied to steal velocity gate [5]:

$$B(f)_{VGPO}=e^{-j\pi fT_c}\frac{\sin(\pi T_C f)}{\pi T_C f}$$

$$\sum_{-\infty}^{\infty}\delta(f+\beta ff_{sh}-n/T_{sh}) \quad (6)$$

Namely, DRFM is applied to generate time delay pulses (in RGPO technique) and frequency shifted pulses (in VGPO technique). Eco delay of a target is done only in Tc time interval and due to discrete DRFM, the electronic attack systems only can delay the pulse in discrete steps td. Thus:

$$\beta = t_d$$

Td should be selected that totally time delay (K), the pulse returning the false target doesn't exceed the tracing limit of radar.

Pulse delay is done in ts interval to create maximum good velocity to deceive the radar and it should be calculated as following:

$$V=\frac{ct_d}{t_s} \quad (7)$$

Time spectrum of output signal is calculated as following to steal VGP gate [5]:

$$y_{syn}(t)\approx(P_\tau(t)\otimes\sum_{n=-\infty}^{\infty}\delta(t-nT_r))e^{j2\pi f_0 t}$$
$$(P_{Tc}(t-Tc/2)\otimes\sum_{n=-\infty}^{\infty}\delta(t-nTc))e^{-j2\pi(f_0\beta/Tc)t}$$
$$P_{Tsyn}(t-Tsyn/2)\otimes\sum_{n=-\infty}^{\infty}\delta(t-nTsyn))e^{-j2\pi f_{syn}t})$$

(8)

Where, T_{SHF} is updating period of phase. Output signal spectrum is achieved as following [5]:

$$D_{syn}(f)=B(f)\otimes C(f)=$$
$$e^{-j\pi fT_c}\frac{\sin(\pi T_C f)}{\pi T_C f}\sum_{-\infty}^{\infty}\delta(f+\beta f_0 f_c-n_1 f_c)\otimes$$
$$e^{-j\pi fT_c}\frac{\sin(\pi T_C f)}{\pi T_C f}\sum_{-\infty}^{\infty}\delta(f+\beta ff_{sh}-n/T_{sh})$$
$$=\sum_{-\infty}^{\infty}\left(e^{-j\pi fT_c}\frac{\sin(\pi T_C f)}{\pi T_C f}\otimes e^{-j\pi fT_c}\frac{\sin(\pi T_C f)}{\pi T_C f}\right)$$
$$\bullet\sum_{-\infty}^{\infty}\delta(f+\beta f_0 f_c-n_1 f_{sh}-f_{syn}-n_2/f_{sh})$$

(9)

$$\left|D_{syn}(f)\right|^2=\sum_{-\infty}^{\infty}\left(e^{-j\pi fT_c}\frac{\sin(\pi T_C f)}{\pi T_C f}\otimes e^{-j\pi fT_c}\frac{\sin(\pi T_C f)}{\pi T_C f}\right)$$
$$\bullet\sum_{-\infty}^{\infty}\delta(f+\beta f_0 f_c-n_1 f_{sh}-f_{syn}-n_2/f_{sh})$$

(10)

$$f_{syn}=f_c-f_{shift} \quad (11)$$

It can be said that the harmonics of DRFM output signal spectrum are in correct product of $n_1 f_c + n_2 / f_{sh}$ with the centrality of frequency $\beta f_0 f_c - f_{sym}$ hertz. The amplitude of the existing harmonics is defined by sinc function. The existing sinc function in this equation determines that the greatest existing harmonic ranges are occurred in the distance

$-0.5 f_{syn} \le f \le 0.5 f_{syn}$.

We should consider that harmonics are in the distance fc. Sinc function in the distance ranging $-0.5 f_{syn} \le f \le 0.5 f_{syn}$, are greater than 0.6 and the highest value is dedicated to frequency zero. But the next harmonic is occurred in the distance $f_{syn} \le f \le 2 f_{syn}$ or $2 f_{syn} \le f \le f_{syn}$ and they have amplitude less than 0.22. Based on the reduction trend, the existing harmonic amplitude is occurred in the distance between $-0.5 f_{syn} \le f \le 0.5 f_{syn}$ .To define the harmonic location with the greatest amplitude, we should search n in this term.

$$-0.5 f_{syn} \le \beta f_0 f_c - f_{sh} - n_1 f_c - n_2 f_{sh} \le 0.5 f_{syn}$$
(12)

$$f_p \begin{cases} 0, \beta f_0 - \lfloor \beta f_0 \rfloor - \lfloor 2\beta f_0 \rfloor = 0 \\ \pm f_{syn/2}, \beta f_0 - \lfloor \beta f_0 \rfloor - \lfloor 2\beta f_0 \rfloor = -0.5 \\ \beta f_0 f_c - f_{sh} - n_1 f_c - n_2 f_{sh}, \beta f_0 - \lfloor \beta f_0 \rfloor - \lfloor 2\beta f_0 \rfloor > -0.5 \\ \beta f_0 f_c - f_{sh} - n_1 f_c - n_2 f_{sh}, otherwise \end{cases}$$
(13)

In the above terms, fp as harmonics frequency shifts with the greatest amplitude to frequency f=0HZ. The frequency location of the above harmonics are followed in the following terms.

$$f = f_p + nf \quad (14)$$

3. SIMULATION RESULTS

For a technique-based DRFM, VRG with maximum delay 10µs and walk time=10s, the changes rate are calculated as pull- off $\alpha = 10\mu s / 10 = 1 \times 10^{-6}$. As the sending frequency of radar is f0=9GHZ as td=6.67ns is selected, ts is selected as the maximum good velocity is provided to deceive the radar. Assuming that the source target goes to the enemy targets with the velocity 800m/s. To reduce this velocity from the view of the enemy radar to 312.5m/s, ts is calculated as following:

$$v = c.t_d / t_s = 312.5 \Rightarrow t_s = 6.4ms \quad (15)$$

After the selection of td,ts, we can calculate TC=3.8ms. In deceiving the range of sinc functions showing various harmonics of output spectrum is separated by fc=222.2HZ. Also, the main harmonic frequency shift to f=0HZ is equal to fp=29HZ. To deceive shift velocity, it creates a fixed Doppler to the source. In Figure 1, pulse radar output signal spectrum with pulse width 0.004 and pulse repetition distance 0.0038 is determined by the number of pulses 100 and radar output frequency is equal to 30 megahertz.

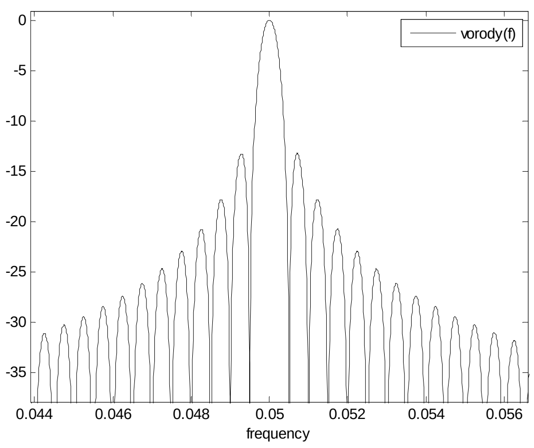

Fig. 1. The spectrum of Radar output signal

In figure 2, pulse delay in discrete steps td=6.67ns and time interval ts=6.4ns and pulse width 0.004 and pulse repetition distance 0.0038 with fixed Doppler shift with fd=52.5 is shown. Of sinc functions showing various harmonics of output spectrum are separated by $f_c + f_d = 284.7Hz$. Also, the main harmonic frequencies shift to frequency fd=52.5HZ is equal to fp=71.5HZ.

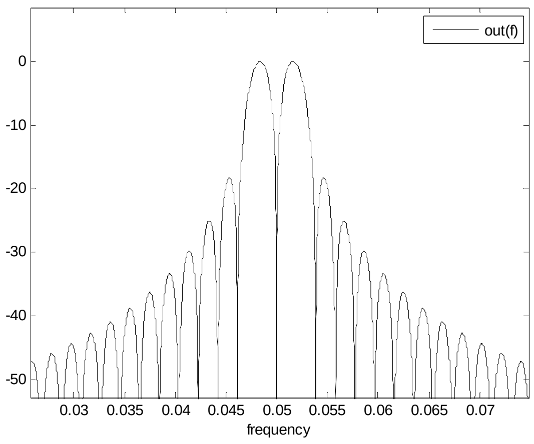

Fig. 2. The output signal spectrum VRG to steal the distance and velocity gate

4. CONCLUSION

In the current study, an analysis was made on DRFM output signal to steal VRG. By this state and the results of simulation, we proved that DRFM output signal to deceive VRG is not completely similar to input radar signal DRFM. The discrete nature of linear DRFM is the reason of the small movement of central frequency and spectrum lines. The central frequency movement size, the harmonics amplitude and places depend upon radar, DRFM and VRGS parameters. Due to the importance of these harmonics and their influence on electronic war systems performance, we can not ignore it. These harmonics are of great importance for exact evaluation of the threats of electronic war techniques by signal analyzers. Finally, if the discrete nature of DRFM affects other techniques of electronic war as stealing angle gate, it is required to generalize simulation and analysis for parabolic VRGS technique.

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