Research on Signal "Batch-increasing" Phenomenon of Superheterodyne Reconnaissance Receiver

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***Abstract*-For the superheterodyne reconnaissance receiver detected "signalBatch-increasing" phenomenon, research on radar signal sand the intercepted characteristics of reconnaissance receiver from the frequency domain, pointed out that "Pulse-width split" and "Pulse-width truncated" caused by Emitter signal spectrum loss is the reason of "Batch-increasing",On this basis, analyzed the strategies of "Batch-increasing" signal processing .**

Keywords- Superheterodyne Reconnaissance Receiver;Batch-increasing;Pulse-width split;Pulse-width truncated

I. INTRODUCTION

Radar reconnaissance signal generation relies on electronic intelligence reconnaissance (ELINT)system, electronic support measures (ESM) system and radar warning(RWR) system[1], the emitter signal sorting is the key step of ELINT, ESM and RWR system reconnaissance signal processing. And only on the basis of signal sorting, the radiation source parameter identification, positioning, tracking and follow-up treatment can be achieved, so sorting algorithm has important implications for the various aspects of electronic warfare [2].

However, after the investigation found that certain type of superheterodyne radar reconnaissance receiver signal processing capabilities seriously hampered the generation of reconnaissance intelligence, the core and the bottleneck is the type reconnaissance receiver often can not correctly sorting complex emitter signals, "Batch-increasing" phenomenon is serious ("Batch-increasing" is the phenomenon which the same radiation source signal be divided into two or more categories), "Batch-increasing" phenomenon led to a large number of false alarms, which greatly affect the electronic intelligence support combat capability [3].

This article research on the reconnaissance signal "Batch-increasing" problem, simulation and analysis the signal intercepted characteristics of superheterodyne frequency measurement system, Research the “Pulse-width split” and “Pulse-width truncated” phenomenon from the frequency domain. Finally, analysised the "Batch-increasing" reconnaissance signal sorting strategy.

II. SIGNAL INTERCEPT CHARACTERISTICS

Radiation source frequency measuring and recording principle of superheterodyne radar reconnaissance receiver is shown in Figure 1 [4].

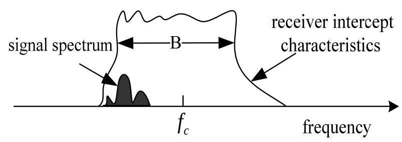


Figure 1 Radiation source frequency measuring and recording principle

When the local oscillation frequency is f_0, intermediate frequency is f_i, the receiver will be formed a frequency window on the frequency axis which center frequency with $f_c = f_0 + f_i$ (or $f_c = f_0 - f_i$) and bandwidth with B, when the signal most spectrum falls within the window, the receiver will detect the signal and records the signal frequency as the center value of the frequency window, the mathematical model can be expressed as

$$RF = \begin{cases} f_c & SIGNAL \quad DETECTED \\ NO & SIGNAL \quad NOT \quad DETECTED \end{cases} \tag{1}$$

The above formula for the received signal timing the center value of the frequency window of the superheterodyne receiver, the antenna signal is not intercepted, the RF parameter is not output.

Superheterodyne receiver intercept radar signal by frequency domain scanning. The radar signal has a certain bandwidth, especially some of the pulse compressed radar signal occupy more wider band. When radar reconnaissance receiver working, reconnaissance receiver bandwidth and radar signal spectrum will appear the three states as shown in Figure 2.

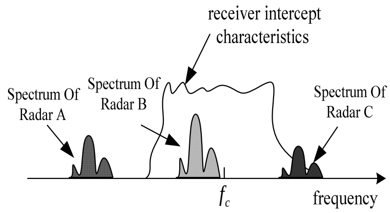


Figure 2 Three states of superheterodyne receiver frequency domain interception

According to the above figure, the three intercepted status of the superheterodyne reconnaissance receiver respectively: Can not be intercepted, such as the state of the spectrum A; Normal intercepted, such as the state of the spectrum B; Incomplete intercepted (The spectrum lossing), such as the state of the spectrum C.

Incompletely intercepte state will cause the radar signal spectrum loss, which will lead to a serious distortion of the pulse envelope. The actual reconnaissance signal analysis found that the distortion of the pulse envelope will lead to the failure of the sorting algorithm, and cause Batch-increasing, especially for large pulse width, pulse modulation waveform L-band surveillance radar remote search will cause a large number of false measurements due to the loss of radar signal spectrum, more common phenomenon is the " pulse-width split" and "pulse-width truncation", the following simulation analysis of the causes of these two phenomena.

III. EASE OF USE

A. The emitter signal spectrum loss led to the pulse width splitting

Assuming a radar operating frequency is 1200MHz, pulse modulation is V-type frequency modulation, bandwidth is 5MHz; Receive bandwidth of superheterodyne receiver is 10 MHz,frequency alignment 1193-1203MHz; Sampling interval $T_s = 3.9 \times (1e-9)s$ [5]. The time domain pulse waveform and spectrum of radar signal is shown in Figure 3.

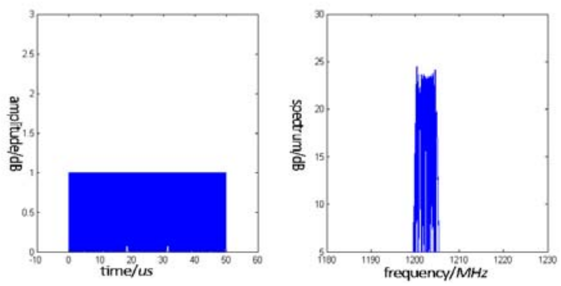


Figure 3 Pulse width 50us V-FM signal time-domain waveform and spectrum

Domain interception characteristics of superheterodyne receiver in frequency domain can be simplified assumed as a band-pass filter, the amplitude -frequency response and phase-frequency response characteristic of reconnaissance receiver which work at the instantaneous bandwidth of 1193-1203 MHz shown in Figure 4.

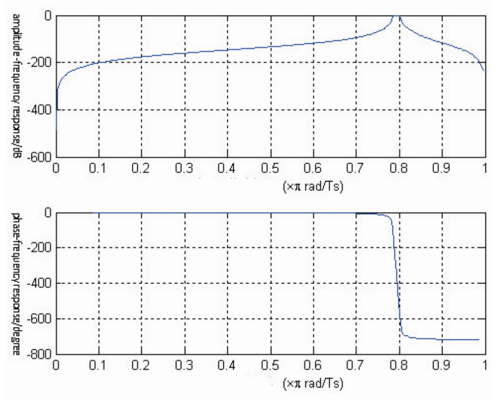


Figure 4 Superheterodyne receiver amplitude-frequency response and phase-frequency response

When V-type FM radar signal pass superheterodyne receiver , the signal envelope had a serious distortion, the time domain pulse shape and the spectrum shows as Figure 5.

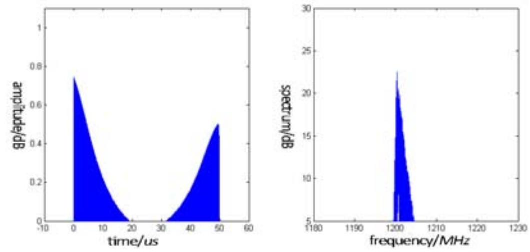
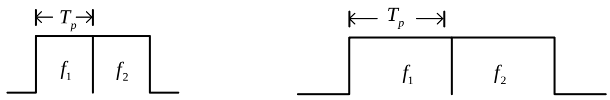


Figure 5 the time-domain waveform and spectrum of V-FM radar signal pass the receiver

The receiver will misjudge a pulse into two, resulting in a signal measurement error, this phenomenon frequently encountered in the actual signal environment. In emitter signal separation processing, radar reconnaissance signal can easily lead to batch-increasing.

B. Pulse-width truncation phenomenon caused by the radiation source signal spectrum loss

Pulse-width truncation is another measurement error caused by the loss of signal spectrum. The development of modern radar technology leads to more complex signal by a solid-state amplifier, phase shifter, and the T / R module consiste phased array radar, "double pulse" is the basic waveform which the phased array search alert radar transmitted[6] , such as the AN/FPS-117 radar of United States, which "double pulse" modulation pulse shows in Figure 6.



Waveform 1	Waveform 2
$B_p = 1.25\text{MHz}$	$B_p = 0.625\text{MHz}$
$T_P = 51.2us$	$T_P = 409.6us$
$\Delta f = f_2 - f_1 = 3.75 \sim 15\text{MHz}$	$\Delta f = f_2 - f_1 = 3.75 \sim 15\text{MHz}$

Figure 6 FPS-117 radar "double pulse" modulation

In figure 6, B_p is the band width, T_p is the signal pulse width, Δf is frequency difference between two pulses. When the the superheterodyne receiver bandwidth covers the pulse spectrum, it can get the correct pulse width measurement value; When the receiver bandwidth covers only one pulse spectrum, it will generate pulse-width truncated phenomenon.

Let the double pulse signal modulation parameter $f_1 = 1200MHz$, $f_2 = 1215MHz$, a single pulse width $T_p = 51.2us$, bandwidth $B_p = 1.25MHz$; Superheterodyne receiver bandwidth is 10MHz, at the 1195-1205MHz; Sampling interval $T_s = 3.9 \times (1e-9)s$. The time domain pulse shape and frequency spectrum of the double pulse is shown in Figure 7.

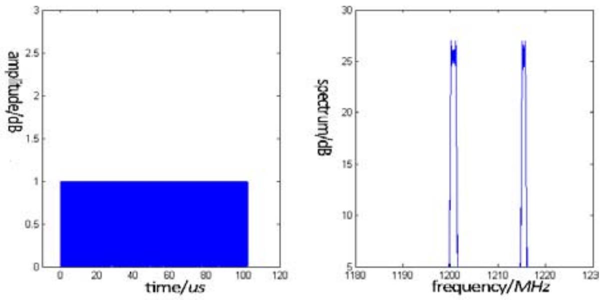


Figure 7 Time-domain waveform and spectrum of "Double pulse"

Intercepting characteristic of the superheterodyne receiver in the frequency domain can be simplified as a bandpass filter, if the superheterodyne reconnaissance receiver instantaneous bandwidth between 1195-1205MHz,the amplitude-frequency response and phase-frequency response characteristics shows in Figure 8.

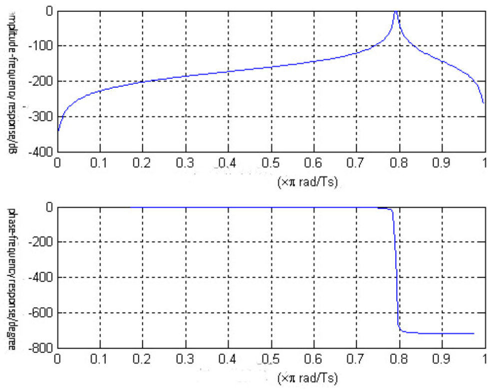


Figure 8 Amplitude-frequency response and phase-frequency response of superheterodyne receiver

Double pulse waveform radar signal pass the superheterodyne receiver , the signal generated a serious distortion, the time domain pulse shape and the spectrum shown as Figure 9.

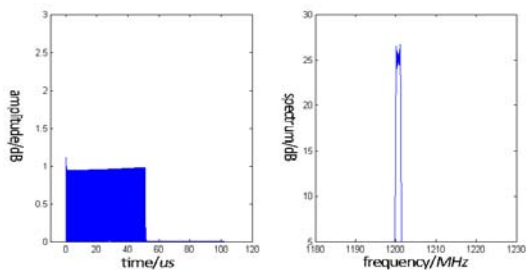


Figure 9 Time-domain waveform and spectrum of double pulse signals which passed the receiver

From the figure, the pulse width truncation often leads to parameter measurement errors, half pulse spectrum falls outside the superheterodyne receiver reconnaissance bandwidth, the signal can not be intercepted.Results the pulse width reduced to half. Measurement error in the signal separation would lead to batch-increasing, such as 51.2us pulse width signal and 102.4us pulse width signal will be divided into two categories.

IV. SIGNAL SORTING STRATEGY RESEARCH IN BATCH-INCREASING CONDITION

According to the signals intercepted characteristics analysis of superheterodyne frequency measurement system in Section 2, signal spectrum loss will causes pulse time-domain waveform serious distortion, which leads to reconnaissance receiver parameter measurement circuit measurement error, and impact PDW, PW, PRI parameters.

When signal spectrum are not completely caught by superheterodyne receiver ,it will cause pulse-width split, Figure 5 shows the distortion waveform of a single pulse width division.When reconnaissance receiver intercept the signal flow, pulse-width distortion will produce a as shown in Figure 10.

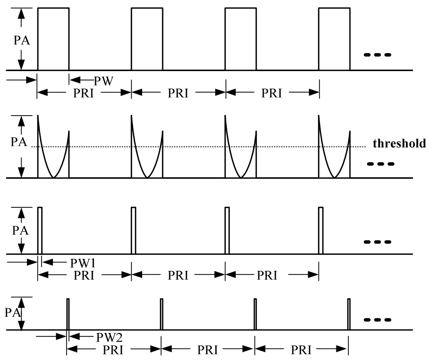


Figure 10 The pulse-width distortion

From figure 10,when the distortion waveform pass pulse-width measuring circuit,it may be measured into two pulse.Use simulation model simulate the above situation, set PW = 117us, PRI = 1710us, reconnaissance receiver measure the PDW fragment shown as table 1.

Table 1 PDW fragment of pulse-width split

RF (MHz)	PW (us)	DOA (°)	TOA (us)	PRI (us)	PA (dB)
1215	17	2.49	3420	100	7.878
1215	43	2.51	3520	1610	8.19
1215	17	2.51	5130	100	9.405
1215	43	2.51	5230	1610	10.197
1215	17	2.52	6840	100	11.16
1215	43	2.52	6940	1610	11.4
1215	17	2.53	8550	100	13.938
1215	43	2.53	8650	1610	14.766
1215	17	2.54	10260	100	15.759
1215	43	2.54	10360	1610	13.923

Use CDIF or SDIF algorithm to sort the PDW fragment in the table, the signals which PRI = 1710us will significantly exceed the threshold, as shown in Figure 11.

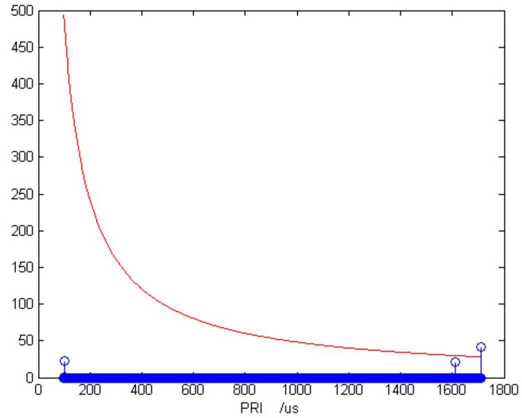


Figure 11 The CDIF histogram of pulse-width split fragment

The original sequence was divide into two sequences, and leads to batch increasing. If use clustering sorting algorithm to deal above data, the 43us and 17us pulse will separation into two groups. However, according to Figure 11, these two sequences have the same PRI, which is a breakthrough to resolve the issue of batch increasing.

Similarly, The pulse-width truncation phenomenon analysised in Section 2 may also leads to batch increasing. Figure 7 shows the distorted waveform of the single pulse, the distorted waveform of the pulse flew shows in Figure 12.

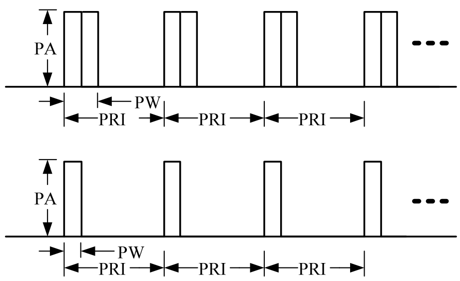


Figure 12 the distorted waveform of the pulse flew

Let the frequency of the double-pulse signal are f_1、 f_2, the radar receiver bandwidth is $B(B > f_2 - f_1)$, the reconnaissance receiver frequency window was shown in Figure 13.

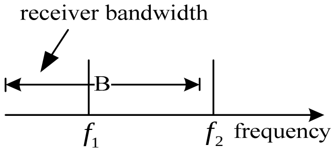


Figure 13 reconnaissance receiver frequency window

The time of complete double pulse and single pulse ratio R is:

$$R = \frac{2(f_2 - f_1)}{B - (f_2 - f_1)} = \frac{2(f_2 - f_1)}{B - f_2 + f_1} \tag{2}$$

If $f_2 - f_1 = 15MHZ$,B = 20MHz, then the value of formula 2 is 6, showing the ratio of the distortion signal usually will more than the correct measurement signal. From figure 12, the pulse envelope distortion greatly affect the accuracy of the measurement of the pulse width, but there is a pattern in the PRI characteristics of the signal. With histogram sorting algorithms for signal processing, you can get the correct sorting results, but in complex radar signal environment,it will difficult forCDIF and SDIF algorithm to achieve effective sorting.

In summary, the main breakthrough point of radiation source sorting in spectrum loss is starting from the signal PRI [7], but we can not directly use the traditional histogram sorting algorithm[8], if the sorting based on clustering and combine batch based on signal PRI characteristic, then determination combine batch or not for the PRI entropy [9], it will be an effective way to solve the superheterodyne reconnaissance receiver bacth increasing problem.

REFERENCES

[1] GustavoL R, Jesus G. Multiple Signal Detection and Estimation using Atomic Decomposition and EM[J]. IEEE Trans. Aerospace and Electronic Systems. 2006, 42(1): 84-102.

[2] Zhao Guoqing, Radar Countermeasures Principle [C]. Publishing House of Xi'an Electronic Technology University.1999

[3] Zeng Wenlong,Zhou Jiang, Impact of Complex Electromagnetic Environment on Electronic Countermeasures Reconnaissance and Solution[J]. National Defense Science and Technology. 2008, (04):54-57.

[4] Jiang Xuqin. Multiple radar emitter environment simulation technology [D]. Thesis of Xi'an Electronic Technology University. 2006: 15-25.

[5] Wang Guoyu, Mathematical simulation and evaluation of radar and electronic warfare systems [M]. BeiJing:National Defence Industry Press. 2004:245-248.

[6] Institute of Nanjing Electronic Technology, The world ground radar manual [M]. BeiJing:National Defence Industry Press. 2005.

[7] Moraitakis I, Fargues M P. Feature Extraction of Intra-Pulse Modulated Signals Using Time-Frequency Analysis[C]. Proceedings of 21st Century Military Communications Conference. 2000: 737-741.

[8] Kawalee A, Owezarek R. Radar Emitter Recognition Using Intrapulse Data[C]. Proeeedings of 15th International Conference on Mierowaves. Radar and Wireless Communications. 2004, 02:435-438.

[9] Sun Panjie,Liu Gang. Research of radar signal clustering method based on PRI entropy [J]. Electronic Information Warfare Technology. 2008, (01):23-25.