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THE PULSE GROUP DEINTERLEAVING

Reviewer: Roman VRÁNA

A b s t r a c t :

This article is focused on the process of radar signal sorting and identification by passive systems. The unambiguous signal source identification and classification is possible only on condition of the right signal source deinterleaving. The deinterleaving based on the knowledge of signal source position is complicated for constant PRI (Pulse Repetition Interval) pulse group signals.

This paper describes the deinterlaving problem solving of the constant PRI pulse group signals by statistical sorting method. The example of the signal source deinterleaving on short time irradiation conditions with false pulses is included.

1. Introduction

This article is focused on the radar signal deinterleaving process that is carried out by passive systems with the TDOA (Time Difference of Arrival) method of radar signal source localization. The deinterleaving means a process of separation of radar signals that are received at the same time. The well-done signal deinterleaving is a necessary condition of an unambiguous identification and classification of a radar signal by passive systems.

2. The deinterleaving and TDOA method

The deinterleaving based on the knowledge of signal source position is one of the best deinterleaving method, but using this method by passive systems with TDOA method is very complicated. The TDOA method of radar signal source localization is based on the measuring of the time of arrival of the radar signal on several geometrically different receiving stations. Of course, this method has a certain degree of ambiguity of the source position determination, especially, in case when the radar signal is created by pulse trains with constant PRI (Pulse Repetition Interval).

The time of arrival (TOA) of the signal depends on the positions of receiving stations and target only [2]. In 2-D case, these times of arrival of the signal are given by

$$
\begin{aligned}
t_c &= f\left(x_c, y_c, x_t, y_t\right) \\
t_l &= f\left(x_l, y_l, x_t, y_t\right) \\
t_r &= f\left(x_r, y_r, x_t, y_t\right)
\end{aligned}
\qquad (1)
$$

where t_c, t_l, t_r are the times of arrival of the signal on receiving stations C, L, R, x_c ,x_l, x_r, y_c, y_l, y_r are coordinates of these stations and x_t, y_t are coordinates of signal source (target). Equation (1) can be written as

$$
\begin{aligned}
\tau_l &= t_c - t_l \\
\tau_r &= t_c - t_r
\end{aligned}
\qquad (2)
$$

where τ_l and τ_r are differences between the times of arrival of the signal on C and L receiving stations and C and R ones, and, simultaneously, they represent hyperbolical coordinates of target. The interval of possible values of hyperbolical coordinates is restricted by geometrical structure of receiving stations [5]. If PRI of the signal is longer than this interval, then the target position is measured unambiguously, see Figure 1.

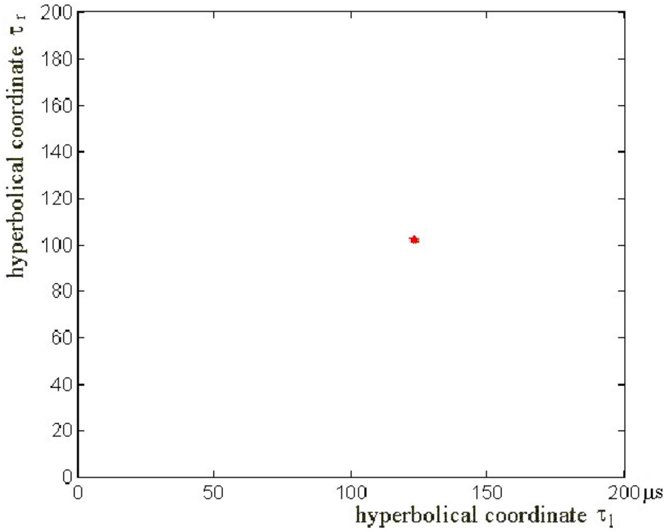

Figure 1 The unambiguous target position measuring, PRI = 200 μs.

In case when the PRI of the signal is shorter than the interval of possible hyperbolical coordinates, then the target position is measured ambiguously, see Figure 2. Consequently, the deinterleaving based on the knowledge of the signal source position cannot be applied.

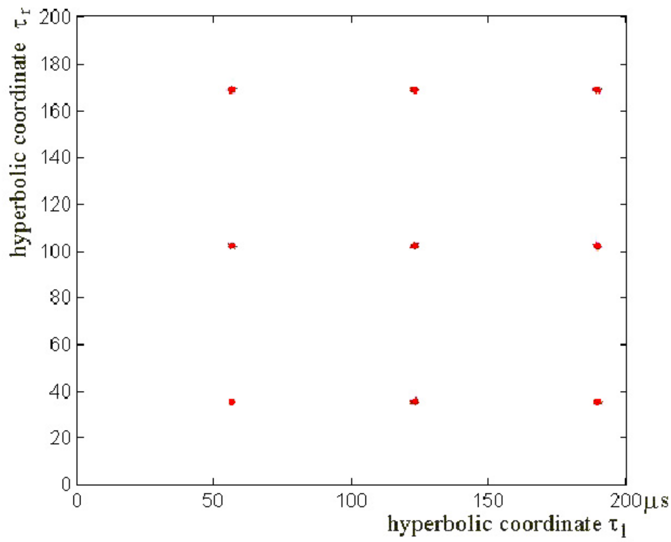

Figure 2 The ambiguous target position measuring, PRI = 66 μs.

The ambiguous target position appears too if two signals with different PRI are received at the same time, see Figure 3. This case is very similar to the receiving of the signal with PRI shorter than the interval of hyperbolical coordinates.

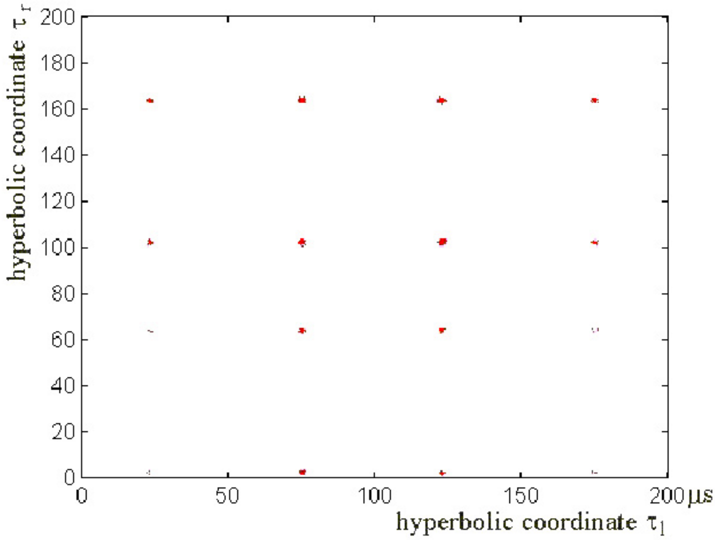

Figure 3 The ambiguous target position measuring, PRI_1 = 200 μs, PRI_2 = 333 μs.

3. The deinterleaving based on the processing of signal PRI

On conditions when the deinterleaving based on the knowledge of the signal source position cannot be used, it is possible performed the deinterleaving based on the knowledge of other parameters of the signal, for example carrier frequency, pulse width etc [4]. Recently, the carrier frequency is the most used signal parameter as a criterion of deinterleaving process.

The next method of the deinterleaving is based on the processing of PRI values of the signal. The separation of signals according to PRI is necessary for signals that are created by pulse trains with constant PRI because sources of these signals have the biggest ambiguity of position measuring. Conversely, the separation of signals with other types of PRI, for example sweep PRI, is possible to perform in agreement with their hyperbolical coordinates, see Figure 4.

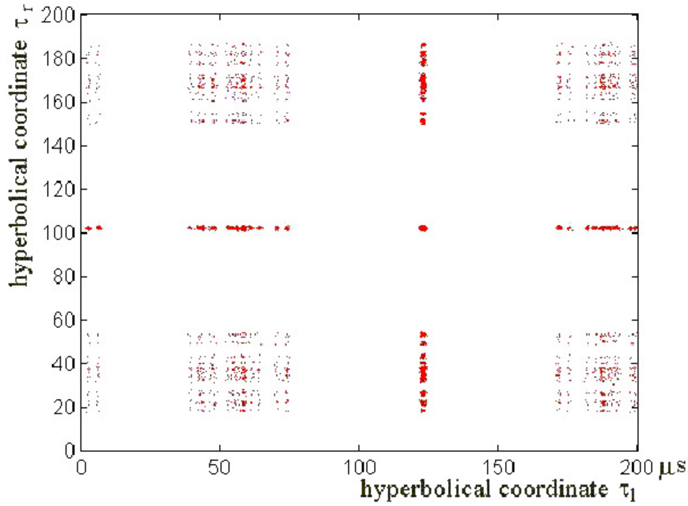

Figure 4 The ambiguous target position measuring, the mean value of sweep PRI = 66 μs; target is visible

Thus, the passive system has to find pulse trains with constant PRI. The similar problem is solved by filter M from N in radar systems [1, 3], but the value of PRI is known in this case. Of course, the value of PRI isn't known in passive systems. Consequently, the N and M requirements are different. By reason of finding the shortest pulse trains, N should be very low and, simultaneously, it should be high by reason of good searching these pulse trains on conditions of missing some pulses. By reason of high credibility, M should be high and, simultaneously, it should be low by virtue of good pulse drop-out resistance. These requirements are optimally executed by the filter with even value of N and with the value of M that is given by M > (N/2 + 1), for example there are filter 3 from 4, filter 4 from 6, filter 5 from 8, filter 6 from 10 etc. With regard to M and N requirements the filter 6 from 8 is an optimal choice. This filter is capable to intercept either the six-pulse group without pulse drop-out or seven-pulse group with one-pulse drop-out or eight-pulse group with two-pulse drop-out and, simultaneously, this filter has the high level of lock-in resistance on multiple PRI.

The performance of these filters can be evaluated by the value of probability of pulse group detection in dependence on the number of missing pulses, see Figure 5.

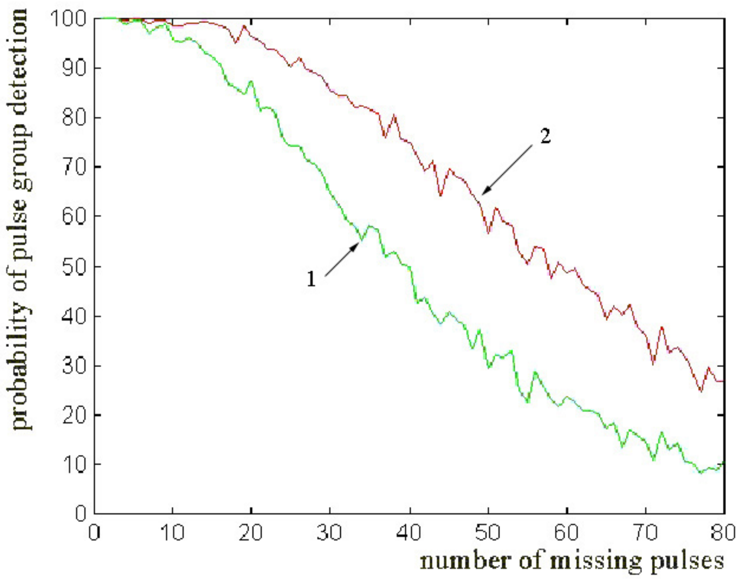

Figure 5 The probability of pulse group detection to the number of missing pulses ratio
(1 [green] – filter 6 from 8, 2 [red] – filter 5 from 8)

4. The operational test of filter on real signal

The operational test of filter 6 from 8 was executed on record of real signals of two surveillance radars. The first signal had PRI_1 = 1665 μs and the second signal had PRI_2 = 1715 μs. Other parameters of these signals were the same. On Figure 6, the time running of PRI of both radar signals is showed. The number of signals cannot be determinate in this case. Detailed time running of PRI at the beginning of the record is showed on Figure 7. The outputs of filter (number of PRI and their values) are displayed on Figure 8. There is visible that the separation of input signals was done correctly.

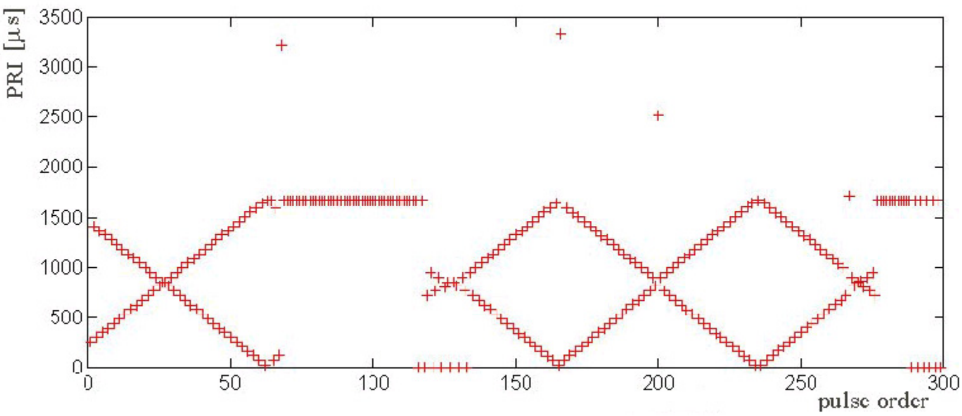

Figure 6 The time running of PRI of two radar signals, PRI_1 = 1665 µs, PRI_2 = 1715 µs

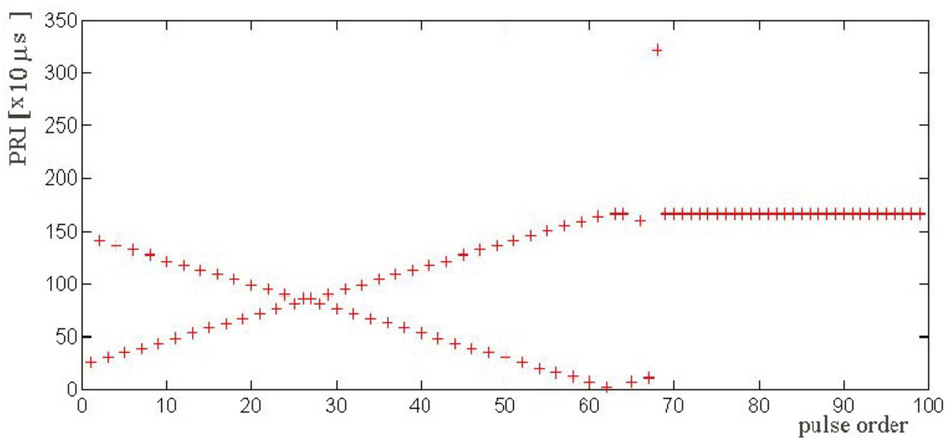

Figure 7 Detailed time running of PRI of two radar signals, PRI_1 = 1665 µs, PRI_2 = 1715 µs

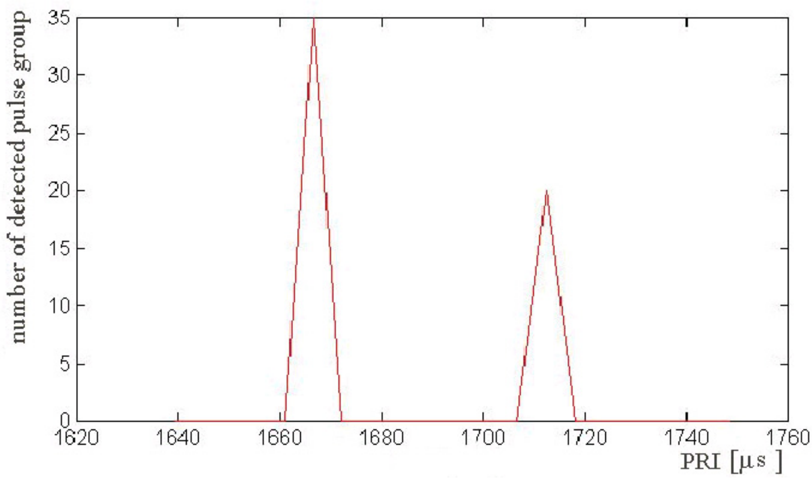

Figure 8 Outputs of filter process

5. Conclusion

The time-varying character of PRI value and value of PRI itself are very important identification attributes of the radar signal because from these attributes the operation of the radar can be determined. The well done deinterleaving process is a necessary condition for the correct value determination of PRI. The deinterleaving based on the knowledge of the source position isn't usable in passive systems with the TDOA method of source localization due to the ambiguity of position determination, especially on conditions of using signal with constant PRI.

This problem can be solved by a special filter, for example filter M from N. Then, the passive system is able to make the deinterleaving according to PRI of the signal. The designed filter 6 from 8 was tested on real radar signals and measured outputs were satisfactory.

References:

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