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Secondary Surveillance Radar Parameters Extraction by Using SIF/IFF Responses Analysis

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Abstract:

This article is focused on the possibility of extraction of Secondary Surveillance Radars parameters by using the responses SIF/IFF form planes. This extraction can be used for different goals, such as transponders location or interrogator testing. This article deals with antenna rotation and pulse repetition interval extraction. For the testing of possibility of these parameters extraction are used measured signal, i.e. received SIF/IFF codes and their time of arrival. The algorithms are tested by MATLAB.

Keywords:

Secondary Surveillance Radar, passive system, parameters extraction

1. Introduction

Secondary Surveillance Radar (SSR) is device, which transmits signal and, instead of its echo, receives and processes the response transmitted by target. SSRs are frequently used as a supplement of primary radars and their antenna is installed on the primary radar antenna reflector. The main difference between secondary radar and primary radars is the necessity of the onboard part – transponder that is integral part of secondary radar technology. The secondary radar system operates on two fixed frequencies: interrogator 1030 MHz and transponder 1090 MHz. Signals are transmitted with vertical polarisation. The transponder receives signals and then it recognizes the interrogation responses by signal with required information. There are some rules of signal shape and information in response called Selective Identification Feature (SIF) or Identification Friend or Foe – IFF where the secondary radar principle is used [1].

This article is focused on the analysis of responses SIF/IFF received by an independent receiver. The received responses (codes) and their time of arrival to the receiver can be used for the extraction of interrogator parameters especially antenna

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rotation period – ARP and Pulse repetition interval – PRI. These extracted parameters can be used (with other extracted parameters) for:

a) SSR's real range evaluation even in different altitudes (flight levels),
b) The plane (transponder) position estimation [2],
c) The estimating of response mode (from the response is not a priori apparent to which mode of the interrogation it is responded) – it can be used for the ambiguity of passive system cancellation,
d) The searching for unknown interrogators and estimating their parameters including their position,
e) The independent monitoring of interrogators activity.

Each of these tasks depends on the ability to extract parameters of interrogators irradiating transponder especially ARP and PRI.

2. Antenna Rotation Period Extraction

There are many ways how to extract an antenna rotation period from the record of received SIF/IFF responses. The simplest way is to select the Time of Arrival (TOA) of one code and to subtract each TOA from each other and then to compute the histogram.

The parameter extraction from SIFF/IFF record algorithm core in MATLAB convention

```
XTT0                                        is TOA vector
XSF0                                        is SIF/IFF vector
i                                           is SIF code that is analyzed

[u,v]=find(XSF0==i);                        Selection of needed SIF/IFF code
X01=XTT0(v);                                and its corresponding TOAs
XM01=(X01./X01)'*X01-X01'*(X01./X01);       Computing subtraction each-each
XX01=reshape(XM01,[1 length(XM01)^2]);      and converting to vector
hist(abs(XX01),600)                         Display of histogram
```

Here are displayed some typical examples of extracting ARP by these algorithms from 40-second length record of received SIF/IFF responses by a real independent receiver. In Figs. 1-8 there are examples with code and number of TOA used for histogram computing. For every histogram, the x-axis represents time in seconds while the y-axis represents the number of combinations with corresponding subtracted time that can be compared to the included number of responses. The number of combinations can be greater than the number of responses, which comes from algorithm itself that generates the whole number of combinations equal to the square of number of responses.

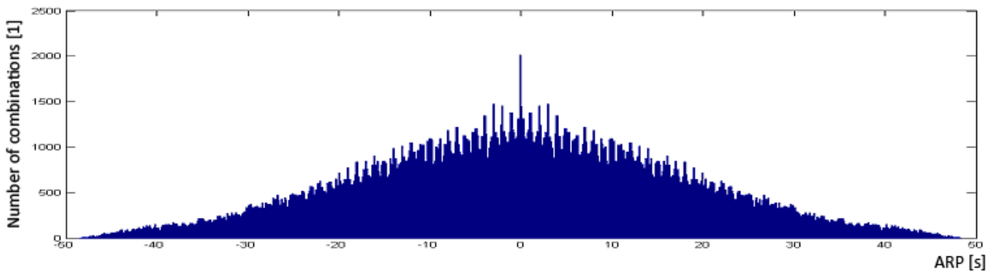

Fig. 1 Code: 41 Number of responses: 304 Remark: ARP = 7.6 s and 4.2 s

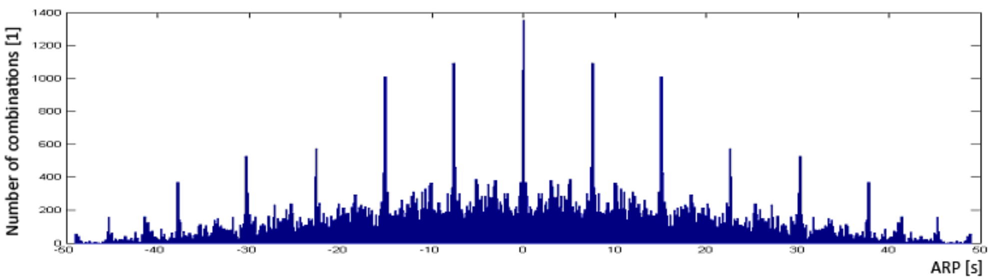

Fig. 2 Code: 80 Number of responses: 566 Remark: ARP = 2.1 s

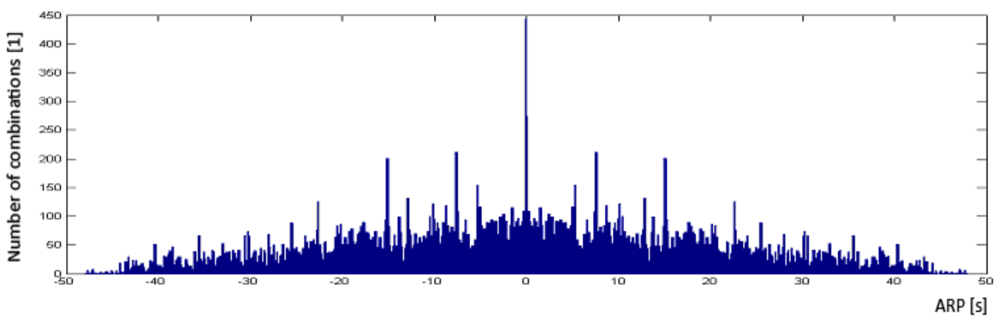

Fig. 3 Code: 210 Number of responses: 169 Remark: ARP = 7.6 s

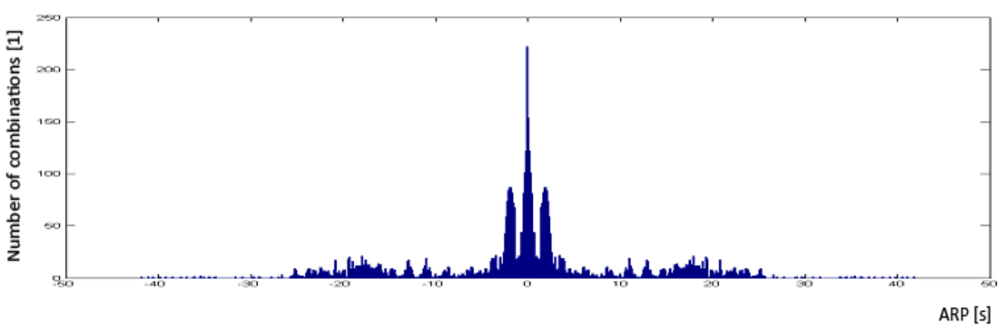

Fig. 4 Code: 880 Number of responses: 68 Remark: ARP = 2.0 s

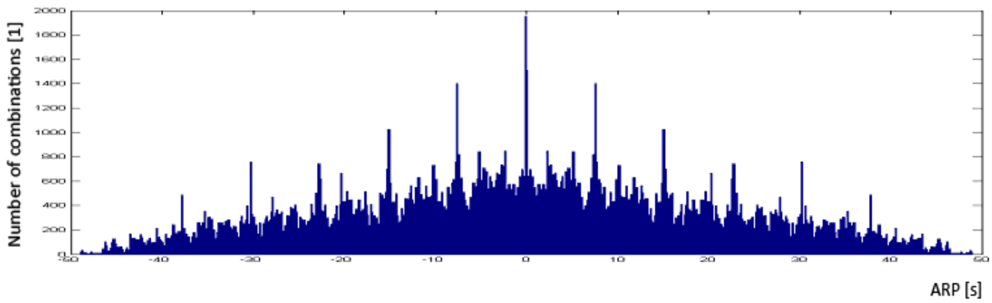

Fig. 5 Code: 1007 Number of responses: 446 Remark: ARP = 7.6 s and 5.2 s

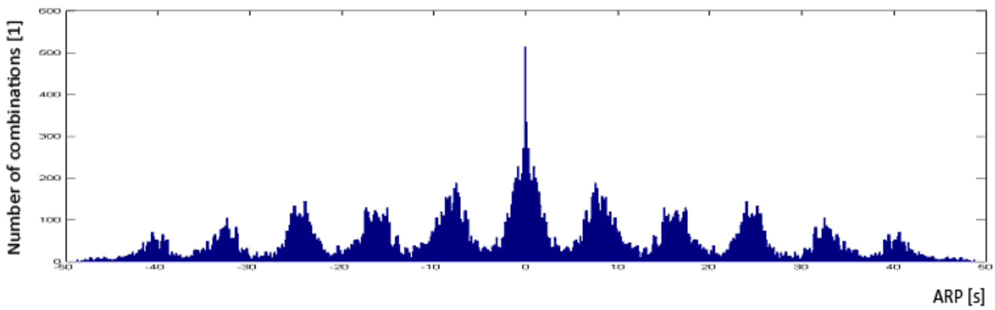

Fig. 6 Code: 1433 Number of responses: 179 Remark: ARP = 7.6 s

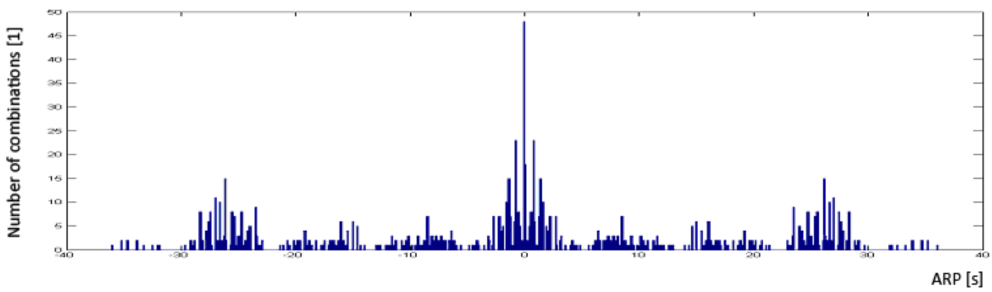

Fig. 7 Code: 2520 Number of responses: 30 Remark: ARP = 0.8 s and 8.5 s

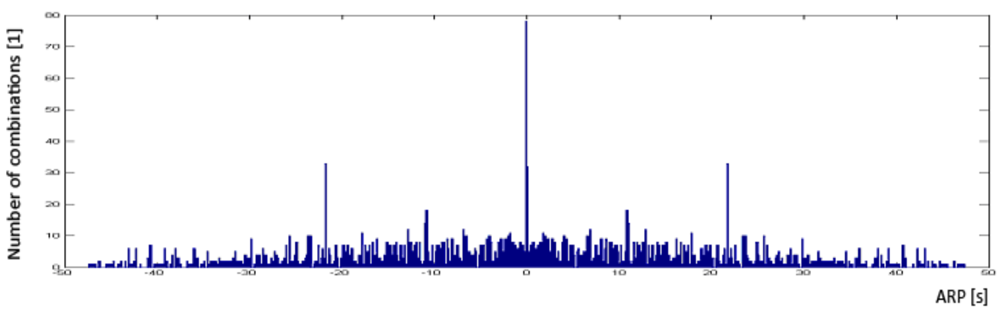

Fig. 8 Code: 3607 Number of responses: 46 Remark: AR = 10.9 s

3. Pulse Repetition Interval Extraction

The extraction of Pulse Repetition Interval is nearly the same as Antenna Rotation Period extraction algorithm. The only difference is the size and granularity of the histogram. The size (scale) is set up to 5 ms, which corresponds to ambiguous range of 750 km so all real PRI should be inside this interval. Figs 9-10 demonstrate some typical examples of extracting PRI histogram.

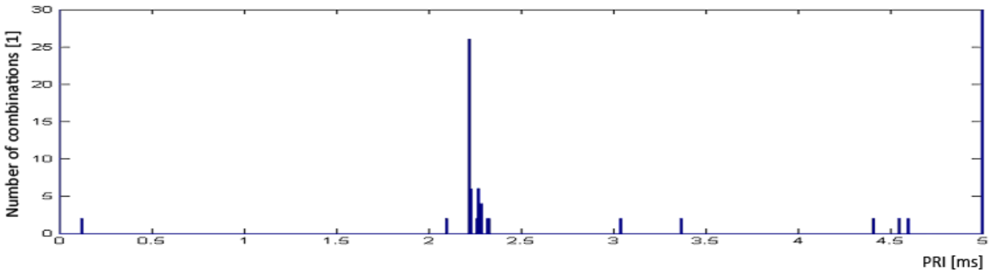

Fig. 9 Code: 41 Number of responses: 304

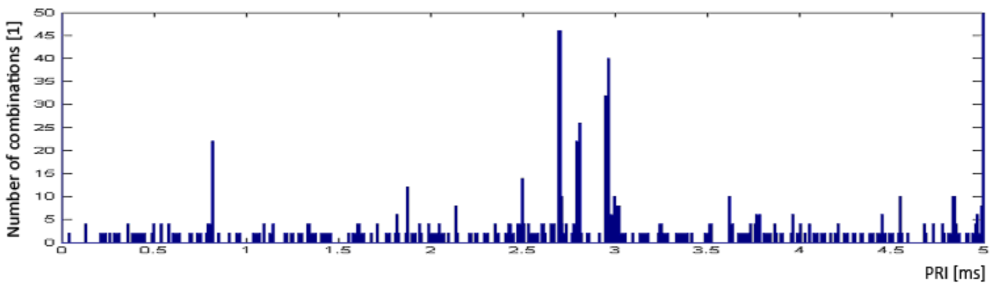

Fig. 10 Code: 761 Number of responses: 1470

4. Combined Analysis – PRI and ARP Simultaneous Analysis

The PRI analysis makes visible the fact the one transponder uses more than one PRI (this fact has been verified by real transponders' parameters). For unambiguous identification of a transponder it is essential to analyze both ARP and PRI. Moreover, there is some higher value of PRI, which represents series of PRI. This higher PRI is better for transponder distinguishing then PRI itself and is called BasePRI. Next reason for the BasePRI establishing is the interrogate mode changing between PRI or the mode sequencing which can be extracted from BasePRI histogram too. Final change is to using of the only positive part of ARP histogram and to shorten the ARP limit to 20_sec, which enables better ARP resolution, especially ARP histogram granularity. The final picture is a tri-histogram which includes PRI-histogram, base PRI histogram and reduced ARP histogram as mentioned below. The examples of tri-histograms are shown in Figs. 11 – 16.

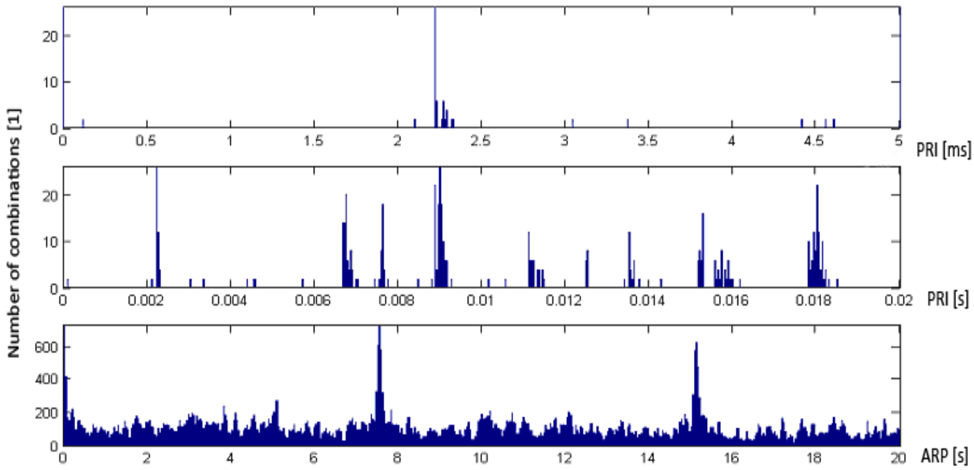

Fig. 11 Code: 41 Number of responses: 304 PRI = 2220 µs (100 nm) ARP = 7.56 s

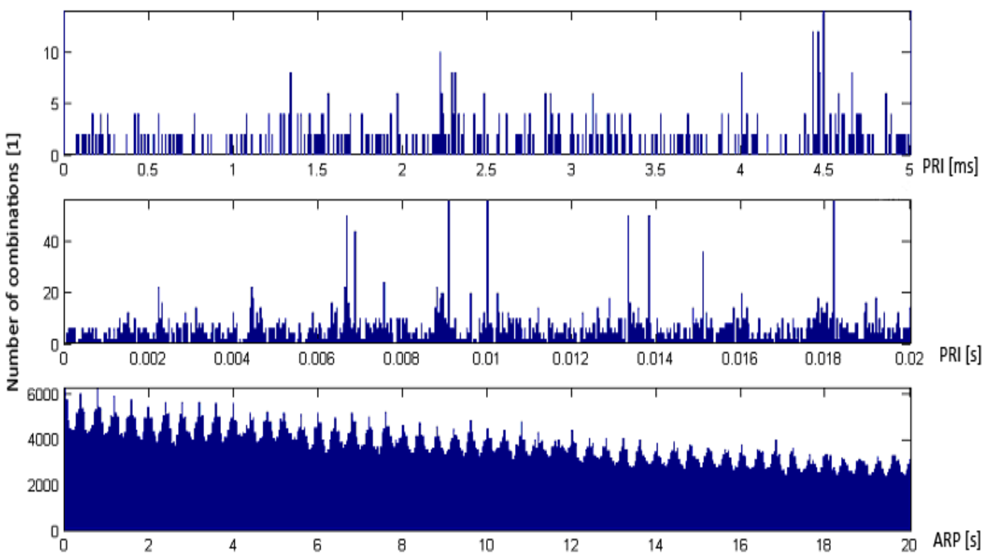

Fig. 12 Code: 1204 Number of responses: 1710 BasePRI = 9180 µs ARP = 0.3821 s

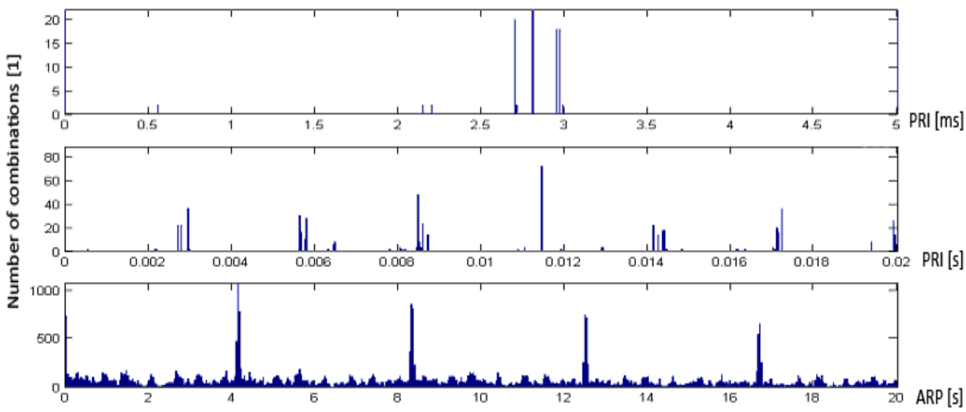

Fig. 13 Code: 3474 Number of responses: 234 BasePRI=11.4 ms TA=4.1625 s

5. Conclusion

Secondary surveillance radars parameters can be used for a lot of different purposes. One of them is to recognize which radar – interrogator irradiates which transponder and in what time. The possibility to estimate these parameters directly by tropo-scatter measuring is complicated due to the interrogator low EIRP comparing to the primary radar. The extraction of these parameters from transponder signals is simpler and furthermore these parameters are usable for transponders location only by the one position receiver [3]. This paper presents features and limitations of a simple method for transponders' antenna rotation period and pulse repetition period extraction. Figures show the influence of a number of responses and number of interrogators and their parameters on histograms shape. The effect of the interrogator – transponder distance is apparent, when the interrogator antenna pattern is in ARP histogram. The interrogator mode sequence can be distinguished and used for recognizing of response mode which is very useful in passive system where the response mode ambiguity problem arise. For Pulse Repetition Interval extraction it is better to use BasePRI descriptor which can better describe the interrogator because of the interrogator PRI sequence complexity.

References

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