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Detection and Extraction of Radio Frequency and Pulse Parameters in Radar Warning Receivers

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Abstract. In this paper we produce the concepts of Radar Warning Receivers Importance of extracting Pulse parameters and carrier frequency is given. The steps to detect and extract Carrier Frequency and Pulse Parameters like Pulse Amplitude, Pulse Width, Time of Arrival, Time of Departure is provided. This extraction results in formation of Pulse Descriptor Words which is the basic first step for Radar Warning Receivers. The simulation is carried in Mat lab were two scenarios are considered. One with independent pulses arriving and next with Pulse on Pulse (POP) situation.

Keywords: Radar warning receivers, Electronic support measures, Radio frequency, Pulse width, Time of arrival, Time of departure, Pulse descriptor word.

1. Introduction

Radar Warning Receivers come under the Electronic Warfare Support (ES) category. They are passive device used to intercept, detect, exploit, analyze and report about the radar signals in the electromagnetic environment of 0–40 GHz. Practically we limit our range from 2–18 GHz. We can split the entire RWR system into two parts of hardware and software. Hardware refers to the detection and conversion of pulse signals to digital format. Software functionality is to detect what type of radar is illuminating our aircraft and to provide aircrew cues. In military, RWR play a important role in emitter identification and it must be sophisticated to suit the complex environment.

2. Basic Architecture of Electronic Warfare

The below figure 1 shows the digital receiver for radar pulse interception. The receiver can be analyzed in three divisions a receiver, a pre-processor and a postprocessor. Initially the antenna identifies the signal and pass it to an RF amplifier where its down converted to an IF frequency. This down converted IF is passed to an analog to Digital convertor which is time sampled to give a discrete time representation. This discrete time data is passed through frequency/spectrum analyzer to perform frequency estimation. Also the same discrete time data is passed to the envelope detector. The detector performs the Hilbert transform where the carrier frequency is removed and only the pulses are obtained. It's with these pulses the Time of arrival (TOA), Time of Departure (TOD) are measured for each pulse.

With each TOA and TOD measured we calculate the Pulse Width (PW). Also the TOA and TOD play a role in fixing the window length to obtain the Carrier Frequency and Pulse Amplitude for this particular pulse. The output of this analyzer holding the Pulse Amplitude and Carrier frequency along with Pulse Width, TOA and TOD from envelope detector is passed to Encoder to produce a Pulse Descriptor Word (PDW). This pulse descriptor word contains all the data present in the signal captured. The next step is the deinterleaving called the pre-processor stage. The pre-processor processes the PDW which contain the six parameters {RF, TOA, TOD, PW, PA} (figure 2)

Of the six parameters described above the deinterleaving is based on the Carrier Frequency. The other two parameters i.e. PW and PA are not used as the data measured is unreliable. The reason is PA depends on the antenna position

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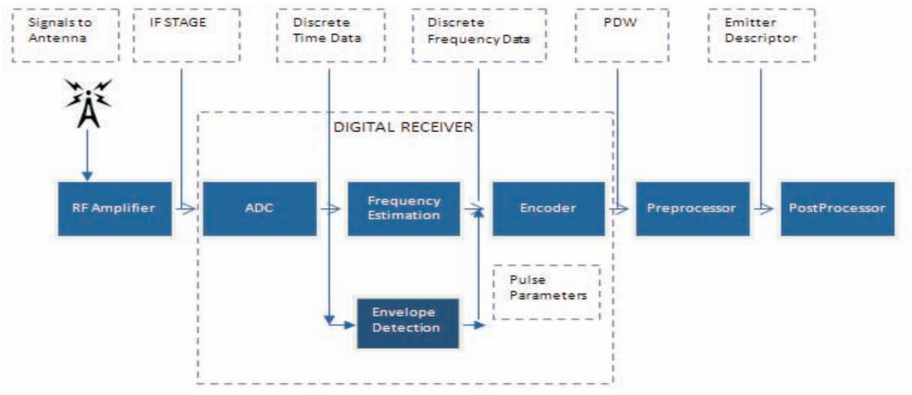

Figure 1. Typical electronic warfare system block diagram.

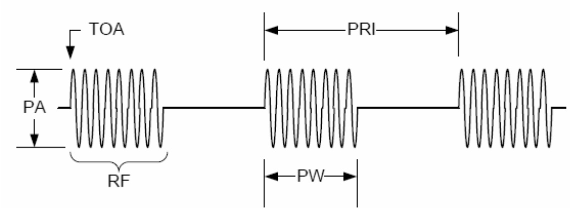

Figure 2. Radar parameters.

and PW is susceptible to multipath. Deinterleaving is a process here where the group of pulses from different emitters need to be sorted out. The sorting helps in calculating the Pulse Repetition Interval (PRI) of a particular emitter. The reciprocal of PRI gives the Pulse repetition frequencies which give the range of an emitter. This output from preprocessor is given as emitter report for post processing. The post-processor functions associate the individual emitter reports to specific emitters using parameters contained in the emitter report. Generally this is carried out by querying the database with specific fields and look for matching to identify the threat. Usually we may obtain more than one threat at a time and we select the threat of greater interest.

3. Pulse Parameters Description

3.1 *Time of arrival (TOA)*

It's an important parameter to help in calculating the PRI and also to tell that a signal is arrived thereby initiating the data acquisition. It's basically done with the help of threshold value. If the present sample amplitude is greater than the threshold and the previous value is less than the threshold we note the counter value which gives the TOA value. Thus dividing this by sampling frequency gives the Time of Arrival.

$$\text{TOA} = \text{TOAccount}/fs$$

3.2 *Time of departure (TOD)*

In the same way as TOA TOD is measured when the present sample amplitude is less than the threshold and the previous value is greater than the threshold we note the counter value which gives the TOD value.

$$\text{TOD} = \text{TODcount}/fs$$

3.3 *Pulse amplitude (PA)*

Since the window length is kept a varying parameter to fit the exact size of the pulse our calculation of pulse parameters seems to be more accurate. Having all the pulse samples and capturing the maximum of them for a particular captured pulse gives the Pulse Amplitude. Mathematically we can express as

$$PA = \max(\text{amplitude samples of a single pulse})$$

3.4 *Pulse width*

Since we are digitally analyzing the signal and also trying to fit pulse by pulse for calculation of PDW we can obtain more accurate pulse width for a pulse by just subtracting TOA from TOD.

$$PW = TOD - TOA$$

3.5 *Pulse repetition interval*

Array of PDWs are formed with the group of pulses received .The first step is to sort and group the signals based on reference with RF measured. Thus signals with group RF1, RF2 etc. Thus with the difference of TOA of second pulse to first pulse in RF1 gives PRI of first emitter. Similarly for other groups we can find. If a group is with single pulse then a warning of PRI can't be measured is displayed. Also Pulse on Pulse (POP) is not considered for calculating PRI and hence not included for grouping and sorting. This increases the chance of not producing false alarms.

$$PRI_i = TOA_{i+1} - TOA_i \forall\, i \in [1, g]$$

Where g is the group of TOA's belonging to particular emitter (RF).

4. Proposed Methodology

Module 1: Signal generation

1. Comp_signal = signal1 (three pulses) + signal2 (two pulses) + signal3 (two pulses)
2. Decide their PA, PW, TOA, and PRI and whether time coincident or non-coincident situation.

Algorithm is applied in calculation of power systems voltages.

Module 2: Signal detection and signal parameter extraction

```
Set the threshold value for signal detection, FFT_ length, sampling _frequency, Sig_duration;
Initialize variable for TOA count, TOD count, Matrix for PDW, pulse_count, PDW_rows;
Hilbert Transform (Comp_signal) to get the vid_ sig
Find the length of vid_ sig
For (Len (vid_sig)) {
If (current_sample>threshold && previous sample<threshold)
   TOAcount = current_sample value; TOA = TOAcount/fs
End if;
If (current_sample<threshold && previous _sample>threshold)
TOD count = current_sample value; TOD = TOD count/fs
End if;
PW= TOD-TOA;
COUNT_PULSE=COUNT_PULSE+1;
Set hamming window_length = TOD count-TOAcount; Find FFT (windowed Comp_signal)
If (amp peak (FFT_output)>= 2) {
DISPLAY (frequencies of PEAKS) &&DISPLAY (PULSE ON PULSE SITUATION)}
Else {
PA = max (FFT_ouput_samples)
Update PDW_MATRIX (RF, TOA, TOD, PW, PA)}
Update PDW rows = PDWrows + 1}
```

Module 3: PRI estimation

```
Freq_array=Unique frequency (PDW_MATRIX)
For (Freq_array (1)) {
Obtain the TOA's of that frequency
If (TOA's >= 2) {
Calculate PRI}
Else {
DISPLAY ('SINGLE PULSE hence can't calculate PRI')} Continue for other unique frequencies;
```


5. Simulation Results

Based on the above algorithm prescribed two situations are considered. One when independent pulses arrive from three emitters and the other when emitter 1 and 2 are time coincident resulting in Pulse on Pulse situation.

5.1 *Case 1*

Emitter1 has Pulse Amplitude = 5; Pulse Width = 300 ns and $RF = 3$ GHz.

Emitter2 has Pulse Amplitude = 8; Pulse Width = 150 ns and RF = 1.5 GHz.

Emitter3 has Pulse Amplitude = 10; Pulse Width = 100 ns and RF = 2.3 GHz.

The RWR is assumed to receive a composite of all three emitters as shown in Figure 3.

The above table shows that obtained RF is with the resolution less than 10 MHz and PW with the resolution of 10 ns. From the obtained table the simulation calculates the PRI for the matching pulses of same RF and is given below.

The TOAs at 1.503906 GHz is 425.100000 2225.100000. Thus PRI is 1800.000000.

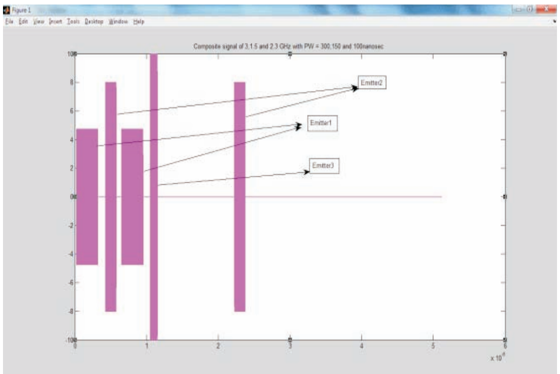

Figure 3. Scenario 1 of three emitters signal generation.

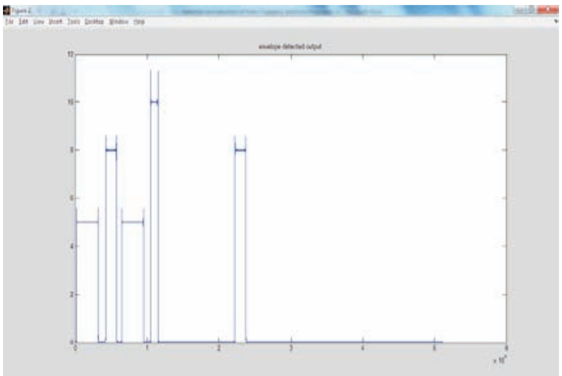

Figure 4. Envelope video detection.

Table 1. Obtained results for scene1.

PULSE	RF(GHz)	TOA(ns)	TOD(ns)	PW(ns)	PA(volts)
1	3.007	20.1	320.20	300.10	4.755
2	1.503	425.10	575.20	150.10	7.999
3	3.007	650.10	950.20	300.10	4.755
4	2.304	1050.00	1150.10	100.10	9.999
5	1.503	2225.10	2375.20	150.10	7.999

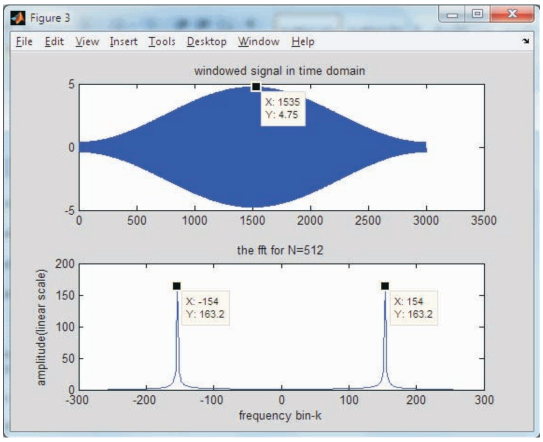

Figure 5. Windowed signal and FFT at 3 GHz.

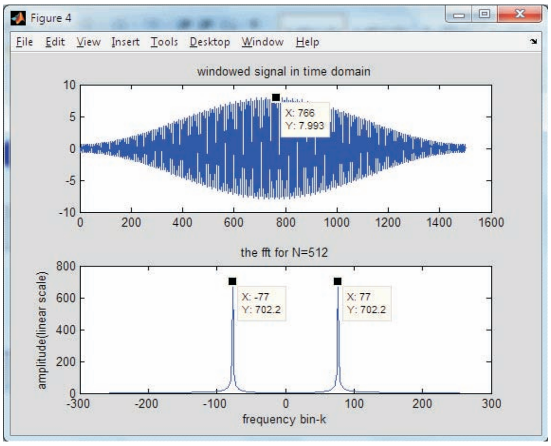

Figure 6. Windowed signal and FFT at 2.3 GHz.

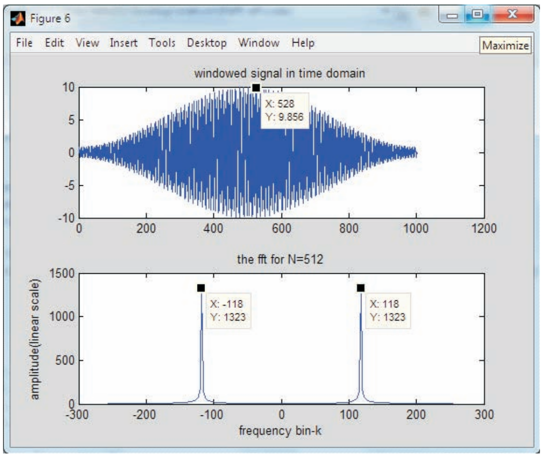

Figure 7. Windowed signal and FFT at 1.5 GHz.

Only one pulse detected with 2.304688 GHZ.
The TOAs at 3.007813 GHz is 20.100000 650.100000 Thus the PRI is 630.000000.

Figure 8. Scenario 2 with POP situation.

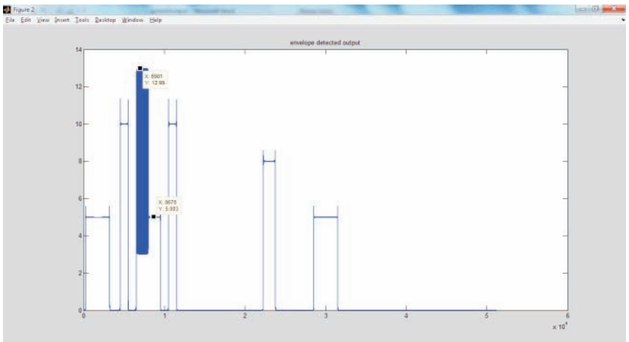

Figure 9. Envelop detection for POP signal.

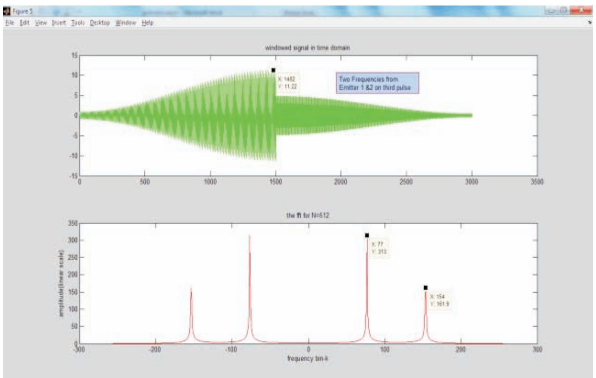

Figure 10. Windowed signal for POP of Emitter1 & 2.

5.2 *Case 2*

Same parameters as case 1 but Emitter1 with three and other two with two pulses into picture .The RWR is assumed to receive a composite of all three emitters as shown in figure 9 where the third pulse is time coincident.

From figure 10 it's clear that even if POP time coincident occurs the windowed FFT can distinguish the frequencies but may result in wrong calculation of PW and PA though TOA can be in the limit of acceptance.

Conclusion

For an aircraft to survive on today's battlefield it is vital to detect and identify hostile radars. To counter these threats military aircrafts are equipped with RWR. This paper discusses the architecture of basic RWR and the method of extracting RF and pulse parameters. The logic takes care of both time independent and dependent pulses and calculates PRI thereby not resulting in false alarms. The future work is to further separate POP signals and calculate their characteristics so that no emitter is missed.

Table 2. Obtained results for scene2.

PULSENO	RF(GHz)	TOA(ns)	TOD(ns)	PW(ns)	PA(volts)
1	3.007	20.1	320.20	300.10	4.75
2	2.304	450.00	550.10	100.10	9.999
3	2.304	1050.00	1150.10	100.10	9.999
4	1.503	2225.10	2375.20	150.10	7.999
5	3.007	2850.10	3150.20	300.10	4.755

*neglected the pulse three as POP which will increase false alarm

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