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### **Generation and Deinterleaving of Radar Signals in Electronic Warfare Environment using SDIF Histogram Algorithm**

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#### **ABSTRACT**

Electronic Warfare is a military action involving the use of electromagnetic energy to determine, exploit, reduce, or prevent the hostile use of electromagnetic spectrum as well as action which retains friendly use of electromagnetic spectrum. A Novel technique proposes the efficient deinterleaving and unambiguous parameter estimation of radar emitters in high dense electronic warfare environment. When the number of adversaries present in the scene with different PRI agilities, Deinterleaving of these gathered PRIs by the ELINT receiver is an important task in the Electronic environment. Deinterleaving of emitters in this paper is based on SDIF Histogram technique and all the results are simulated by matlab tool.

**KEY WORDS:** Electronic Warfare, S-DIF, PRI (Pulse Repetition Interval), ELINT.

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## **INTRODUCTION**

Electronic Warfare is a military action involving the use of electromagnetic energy to determine, exploit, reduce, or prevent the hostile use of electromagnetic spectrum as well as action which retains friendly use of electromagnetic spectrum. EW is commonly divided into three subfields such as ES, EA and EP. Electronic support (ES) is the listening part of EW and this system is used to detect threat signals and display the types and location of transmitters to support situation awareness or cue electronic attack capabilities. Electronic attack (EA) involves measures taken to defeat enemy electronic assets. It includes jamming, chaff and flares, directed energy weapons, and anti radiation missiles. Electronic protection (EP) comprises counter measures to enemy electronic attack<sup>3</sup>.

Besides all these SIGINT (Signal intelligence) is one for information gathering and it is two types which are ELINT (Electronic Intelligence) and COMMIT (Communication Intelligence). The primary objective of an ELINT system is to compile operational data of enemy electronic systems. ELINT is usually carried out on a regular basis, during times of both peace and war. Peace-time operations have the objectives of gathering maximum possible data of enemy, latter ELINT effort is made in order to evaluate the enemy defensive weapons. In general, ELINT serves a strategic role of the enemy, as well as a tactical role in helping to develop or reprogram appropriate EA/ECM and EP/ECCM equipment to meet each threat. The basic targets of ELINT are all types of radars, which will detect, locate and identify by their parameters in their operating modes (Search, Acquisition, and Tracking). All the parameters of each target radar are measurable ones, such as Operating Frequency, Power, mode of operation, Sort of Modulation, Pulse Width (PW), Pulse Repetition Frequency (PRF), Time of Arrival (TOA), Pulse Amplitude (PA), Directional of Arrival (DOA), and Pulse Repetition Interval (PRI)<sup>2</sup>. In this paper the ultimate aim is to deinterleave the received interleaved structure by using Pulse width (PW), Pulse repetition interval (PRI) as primary and secondary parameter with the help of SDIF (Sequential Difference Histogram) algorithm.

## **RADARS IN EW SYSTEM**

Radar (RAdio Detection And Ranging) is used for detection, identification and imaging of objects in the environment. For this purpose, radars emit electromagnetic energy, collect and process the reflections from these emissions, this task is called deinterleaving. After deinterleaving, Radar will measure the type of received pulse along with its parameters and also finds the range and velocity of the enemy. Basically there are different pulses to search the enemy in the space. All these pulses are unique and each having different Pulse repetition interval, so based on this feature all these signals are calling as PRI based signals, which are follows,

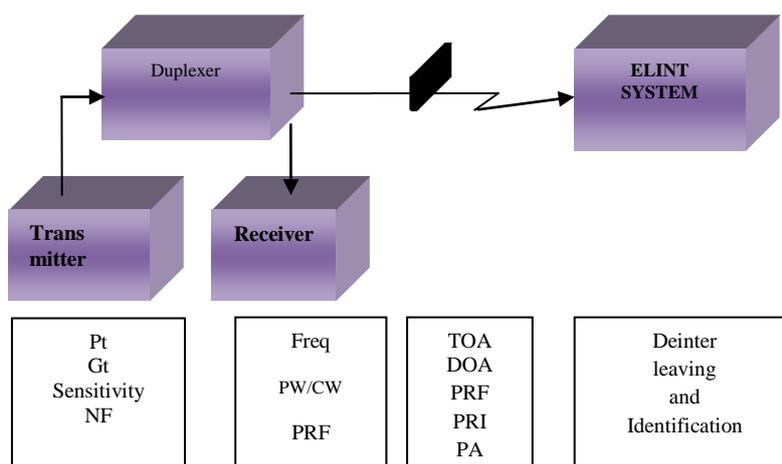


Figure1. Radar block diagram

1. Constant PRI.
2. Stagger PRI.
3. Dwell and Switch PRI.
4. Jitter PRI.
5. Agile PRI.

## SIGNAL DESCRIPTION

### 1. Constant PRI.

Radar is said to have a constant PRI if peak variations in PRI are less than 1% of the mean PRI. These variances are assumed to be incidental. If the average PRI value is to be used to estimate the radar's maximum unambiguous range, an accuracy of 1% is sufficient. PRI varies like  $t_1, t_1, t_1, t_1, \dots$ , figure shown in 5.

### 2. Stagger PRI.

Staggered PRI means use of two or more PRIs in a fixed sequence. Roughly, it can be said that PRI is changed from pulse to pulse. The staggered PRI is generally used. PRI varies like  $t_1, t_2, t_3, t_1, t_2, t_3, \dots$ , figure shown in 6.

### 3. Dwell and Switch PRI.

In this type of radar, several different PRIs are selected for use. The radar transmits pulses at a constant PRI for a dwell time and switches its PRI for the next dwell time. This technique is used to resolve range ambiguities in pulse Doppler radars. PRI varies like  $t_1, t_1, t_1, t_2, t_2, t_2, \dots$ , shown in 7.

### 4. Jitter PRI.

Jittered PRI is large variations in PRI up to 30% of the mean PRI. Such variations are generally used for ECCM. In fact the detection of jittered PRI may be very difficult for EW

systems. If the pulse width and PRI data are varying, such a signal is termed to possess jitter. PRI varies like  $t_1, t_4, t_3, t_2, t_1, t_2$ , shown in 8.

### 5. Agile PRI.

Agile PRI is a frequency hopping PRI, its pulses jumbled in its group for every shift. It is a unique signal and the structure of agile signal varies like  $t_1, t_2, t_3, t_2, t_3, t_1, t_3, t_1, t_2$ , it is shown in 9.

According to basic RADAR principle, when we send above five types of signals into the space having different parameters, these signals will go into the space and be reflected back if there is any target. If all the transmitted signals are reflected back by hitting the target, signals received by the ELINT receiver are interleaved and difficult for the receiver to identify and find the AIM, this difficulty is called the Interleaving problem<sup>4</sup>. Along with own radar reflected signals, sometimes some structured signals and having nearer parameters may also be included, these are called as friendly echoes, which are generated by the enemy radars.

## INTERLEAVING PROBLEM

For the purpose of detecting and identifying radar emitters in the environment, the pulse sequences received from radars are used<sup>1</sup>. The problem of determining the presence of a specific emitter in the environment is a problem of detecting a consistent pulse sequence in the incoming stream of interleaved pulses. The structure of received signals from the enemy emitters is a combination of constant PRI, stagger PRI, dwell and switch PRI, agile PRI and jitter PRI etc.

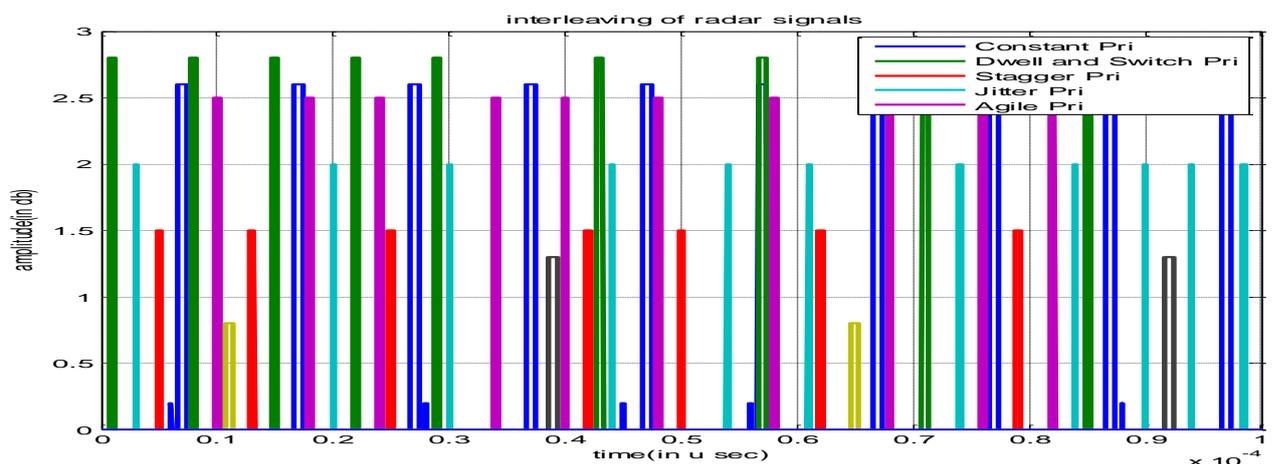


Figure2. Interleaved structure of RADAR Signals

When all these signals having different PRIs, different pulse widths, frequencies and amplitudes. But each pulse train has same frequency, Pulse width and pulse amplitude. This problem can be expressed mathematically as follows. Consider  $N$  signal sources ( $N$  is unknown), each one of

which generates a periodic pulse train with period  $T_i$  where  $i$  is ranging from 1 to  $N$ . If the finite basic pulse used in all trains is denoted by  $g(t)$ , then the pulse received by the  $i^{th}$  source is denoted by  $X_i(t)$

$$X_i(t) = \sum_{n=-\alpha}^{\alpha} g(t - nT_i - \tau_i) \quad i=1, 2, 3 \dots N \quad (1)$$

Delay between each pulse train or reference time is denoted by  $\tau$  when the signals are coming from the environment, some noise is added to the pulse train. The interleaved signal structure  $X(t)$  with noise can be expressed as,

$$X(t) = \sum_{i=1}^N X_i(t) + n(t) \quad (2)$$

Observation noise is denoted by  $n(t)$ . The problem is to determine all periods  $T_i$ , once the  $X(t)$  is given

The above equation (1) represents the interleaved signal structure which includes all reflected pulses and with some observation noise which is shown in figure 2. During pulse sorting process, we will set some threshold to the interleaved structure and the pulses above threshold are taken for consideration while pulses below threshold are considered as noise signals. If PRI is not being detected with considered threshold then it is needed to change the threshold level as optimum to get PRI<sup>3</sup>.

### ELINT RECEIVER

ELINT Receiver main function is collection of data and information useful for strategic planning. It does fine-grain analysis and therefore has a very high sensitivity.

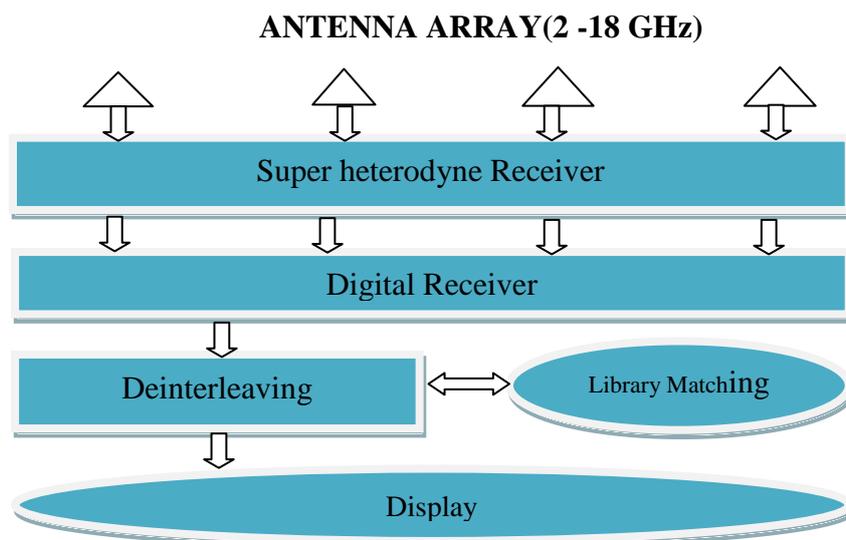


Figure3. ELINT RECEIVER

Its instantaneous bandwidth is far less. Hence it covers one or a few signals of interest. If the data cannot be analyzed at the collection station, it can be stored and analyzed at a later time. It

normally works in peacetime to collect as much data about the adversary. That is gathered as a result of observing the transmissions and there by obtain information about their capabilities. These transmissions can be generally any non-communication emissions and specifically radar emissions. The basic parts in ELINT system is super heterodyne receiver, digital receiver followed by deinterleaving block finally one library matching and display. An array of antennas placed at super heterodyne receiver with frequency range from 0.2 to 18GHz, reflected signals received by the super heterodyne receiver will down converted and pass through the digital receiver.

### ***Super Heterodyne Receiver***

In EW applications, a super heterodyne receiver is often used in conjunction with some other types of wide-band receivers. The wide-band receiver can be used as a cueing receiver to find the frequency of the signals of interest. One such application is to measure the AOA information of an input signal through an interferometric system. Because of the relatively narrow bandwidth, phase matching between different super heterodyne receivers is easier to achieve than in a wide band receiver.

### ***Digital Receiver.***

The most critical element is the analog-to-digital (A to D) converter. The digital receiver receives the signals from the super heterodyne receiver as a intermediate frequency, and it digitizes the all signals. In general all the signals are from the super heterodyne receiver as in continuous form, so all the signal structure as a cluster or interleaved. Digital receiver used to represent the signals as in discrete form, so that it is easy to identify the signal characteristics. Digital receiver is used to convert from analog data to its equivalent digital data having pulse width, frequency, TOA, DOA, and Pulse amplitude, this data is called as pulse descriptor word (PD WORD). When this PD Word applied to deinterleaving block the following algorithm steps will execute.

### ***Library matching.***

Library matching used to verify weather the reflected and received signal is belong to our own radar or enemy radar. This task is don't after deinterleaving part, once the deinterleaved data is matched with library data which means there is an enemy, if it is not matching means that received signal might be noise or some other random signal.

### ***Algorithm for Deinterleaving***

Basically this algorithm is divided into two parts which are

1. Pulse sorting

## 2. Parameter estimation.

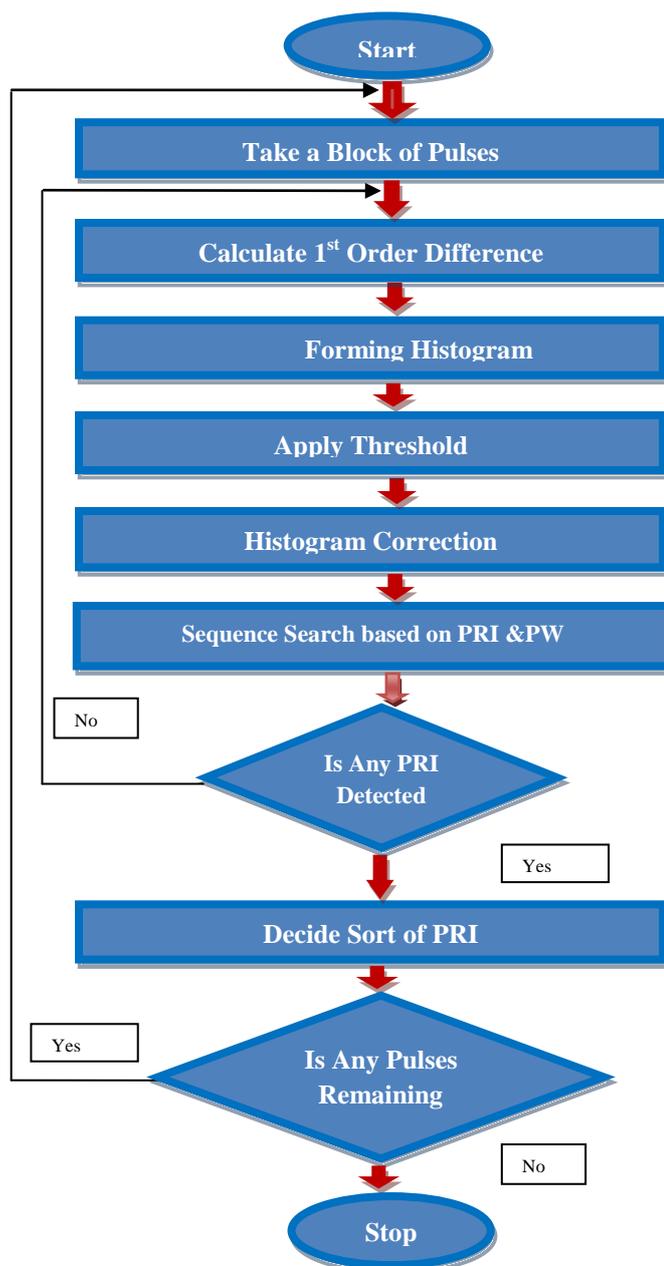


Figure4. Algorithm

**Algorithm steps**

1. Take first bin.
2. Calculate the 1<sup>st</sup> to nth level difference. Calculation of difference is mentioned in eqn.
3. After finding all the differences, and then form a histogram, then finds if any pulses are missing.
4. Expand the sequence at the starting side and also ending side to get clear determination about PRI type.
5. By considering the expanded sequence, correct the sequence (finds the missing pulses and noise signals).

6. Search the entire sequence, if it forms any PRI based on PRI decides the signal type.

7. After proper conformation, record all signal parameters (PRI, TOA, and PW). Repeat the same steps till the end.

After finding all the parameters, just remove the data from the list, because sometimes same PRI sequences may come, so for reducing confusion and also load.

## RESULTS

The below figure represents the constant pri, having equal PRI that is 10 us and total pulses are 10, amplitude is 5, pulse width is 1 us.

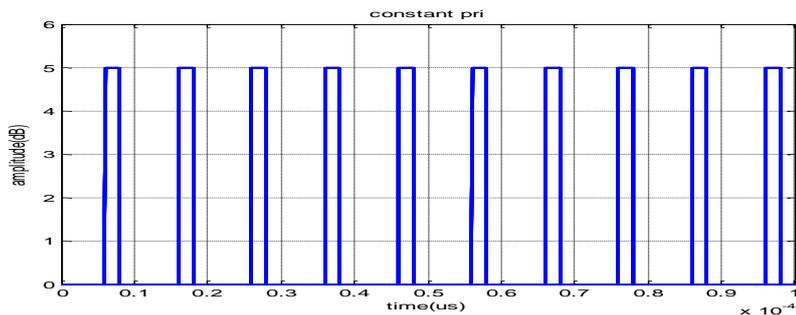


Figure5. Constant PRI

The below figure represents the stagger pri, having 3 PRIs keep on increment and the same set is repeated as 2<sup>nd</sup> set. The PRIs are 8us, 12us, 17us and total pulses are 6, amplitude is 4, and pulse width is 0.8 us

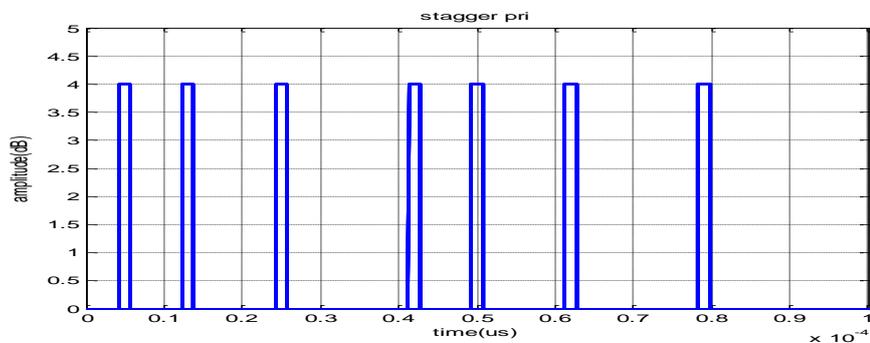


Figure6. Stagger PRI

The below figure represents the dwell and switch pri, having 2 sets of PRIs. The first set have 7 us and the second set have 14 us and total pulses are 9, amplitude is 4.5, pulse width is 0.9 us. In this special signal one pulse is missed at 57 us due to pulse on pulse condition (bad data).

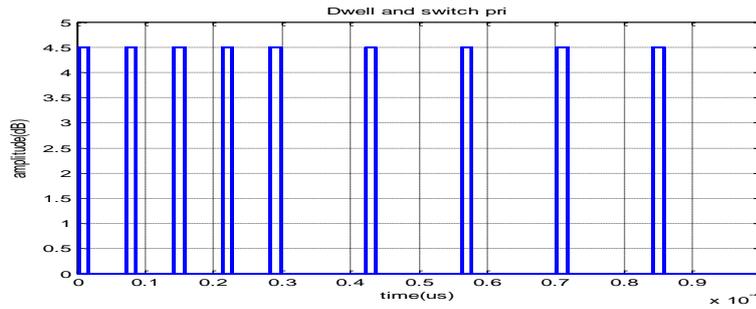


Figure7. Dwell and Switch PRI

The below figure represents the jitter pri, having PRI is in random manner. The PRIs are 17us, 10us, 14us, 10us, 7us, 13us, 10us, 6us, 4us, 4.5us and total pulses are 11, amplitude is 3.5, pulse width is 7 us.

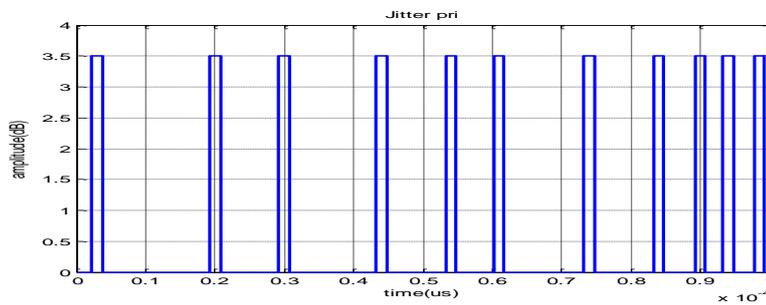


Figure8. Jitter PRI

The below figure represents the Agile pri, having 3 sets of PRIs. The first pri 10 us, the second pri 40 us and third pri is 90, these 3 pris will jumbled in its next shift, amplitude is 4.5, and pulse width is 0.9 us.

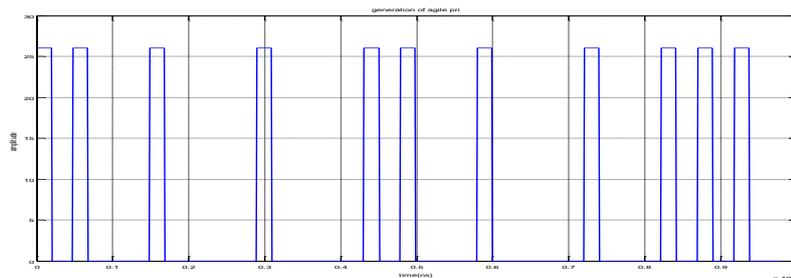
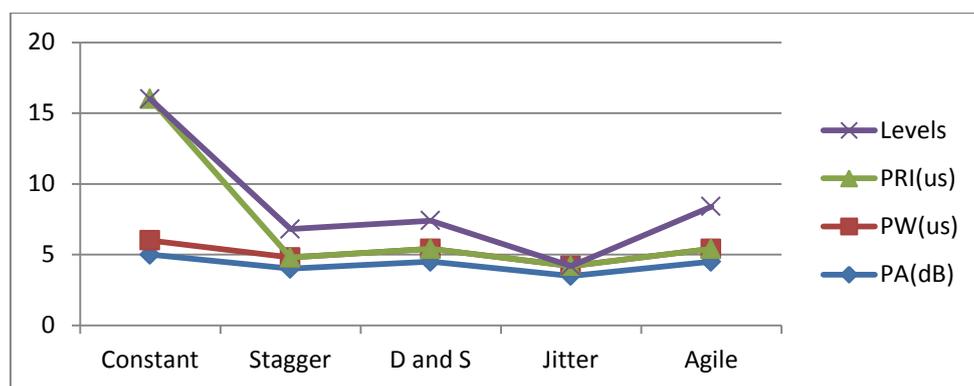


Figure9. Agile PRI

Table1. Comparison of all PRIs

	S-DIF			
	PA(dB)	PW(us)	PRI(us)	Levels
Constant	5	1	10	-
Stagger	4	0.8	8, 12, 17	2
D and S	4.5	0.9	7,4	2
Jitter	3.5	0.7	17,10,7,13	-
Agile	4.5	0.9	10,40,90	3



Graph 1. Comparison of all PRIs

## CONCLUSIONS

The PRI based Generation, Interleaving and deinterleaving is successfully implemented in ELINT systems, while in the ES systems. This project presents aspects of PRI analysis of different radar signals Generation, interleaving and deinterleaving with simulated signals. The SDIF algorithm using TDOA (Time Difference Of Arrival) allows for more efficient analysis of long pulse sequences of periodic changes in PRI such as (Constant, stagger, dwell and switch, Agile and Jittered).

The parameters like time of arrival (TOA) in  $\mu$ s, pulse width (PW) in  $\mu$ s and pulse repetition interval (PRI) in  $\mu$ s for different emitters are calculated and tabulated in table 1.

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