# Chapter 2

## Literature Review

Initial acquisition of the code phase is generally the most difficult to be performed in a spread-spectrum system. From searching through the literature which discusses PN acquisition techniques, we found that many techniques had been studied and proposed to improve the performance of the acquisition system. Each scheme has its advantages and disadvantages. We can group the research into 3 categories:

- Research which develops the conventional schemes

- Research which proposes a new schemes

- Research which analyzes or models the PN acquisition.

First, conventional PN acquisition schemes are summarized.

### 2.1 Conventional PN Acquisition Schemes

In the classical PN acquisition technique, the most common concept bases on the maximum-likelihood (ML) algorithm. The first improved scheme using ML algorithm was proposed by Sage [24], which was called a serial search scheme. It uses the incoming signal to correlate with the local signal and then the correlation result is compared with the threshold. If it exceeds the threshold, the verifying mode is initiated. Otherwise, the phase is updated by $\Delta T_c$, where $\Delta \le 1$ and $T_c$ is the chip duration, and the search continues to the next phase. The scheme is very simple and easy to implement. A disadvantage of this scheme is that it takes much time to acquire the correct phase. Figures 2.1 and 2.2 depict a coherent and a noncoherent serial search schemes, respectively. Equivalent baseband signals $v(t)$ and $u(t)$ are used to represent the input signals in the coherent and noncoherent cases, respectively.

For the coherent scheme, the input signal is correlated with the local PN signal and then the correlation result is integrated from $n'(l-1)T_c$ to $n'lT_c$ where $n'$ is integration length and $l \in \{1,2,3,...\}$. After that the integrated signal is compared with threshold for testing alignment. If it exceeds the threshold, the tracking circuit starts. Otherwise, the PN generator is updated phase by $T_c$.

For the noncoherent scheme, the input signal is correlated with the local PN signal. The correlation signal is integrated from $n''(l-1)T_c$ to $n''lT_c$ where $n''$ is integration length and then the real part and imaginary part of the integrated signal are squared and summed together. The result of summation is compared against the threshold for checking alignment. If it exceeds the threshold, the tracking circuit is initiated. Otherwise, the PN signal phase is updated by $T_c$.

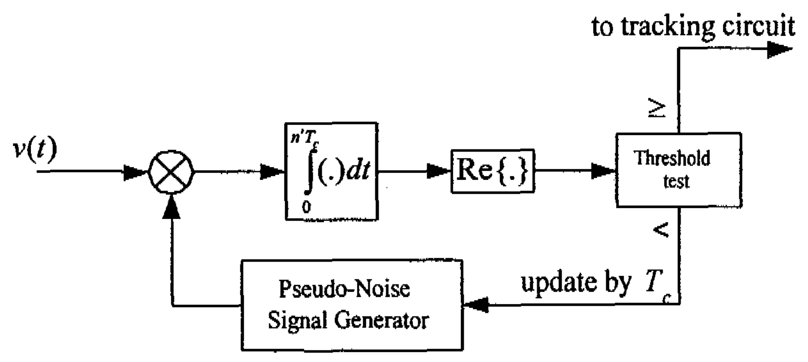


Figure 2.1:A conventional coherent serial search scheme

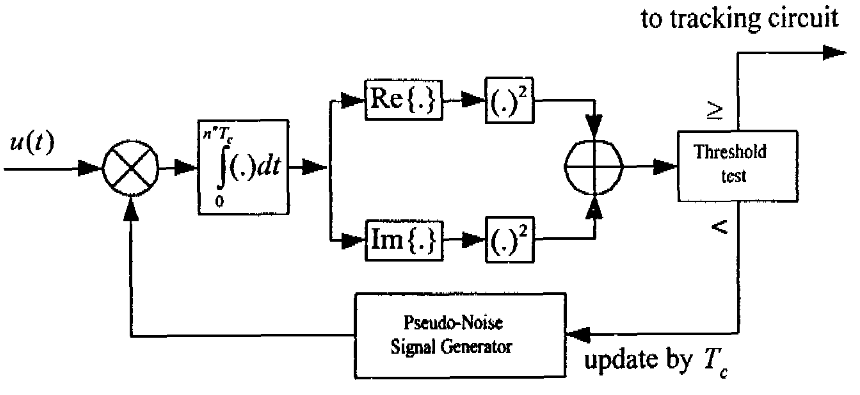


Figure 2.2: A conventional noncoherent serial search scheme

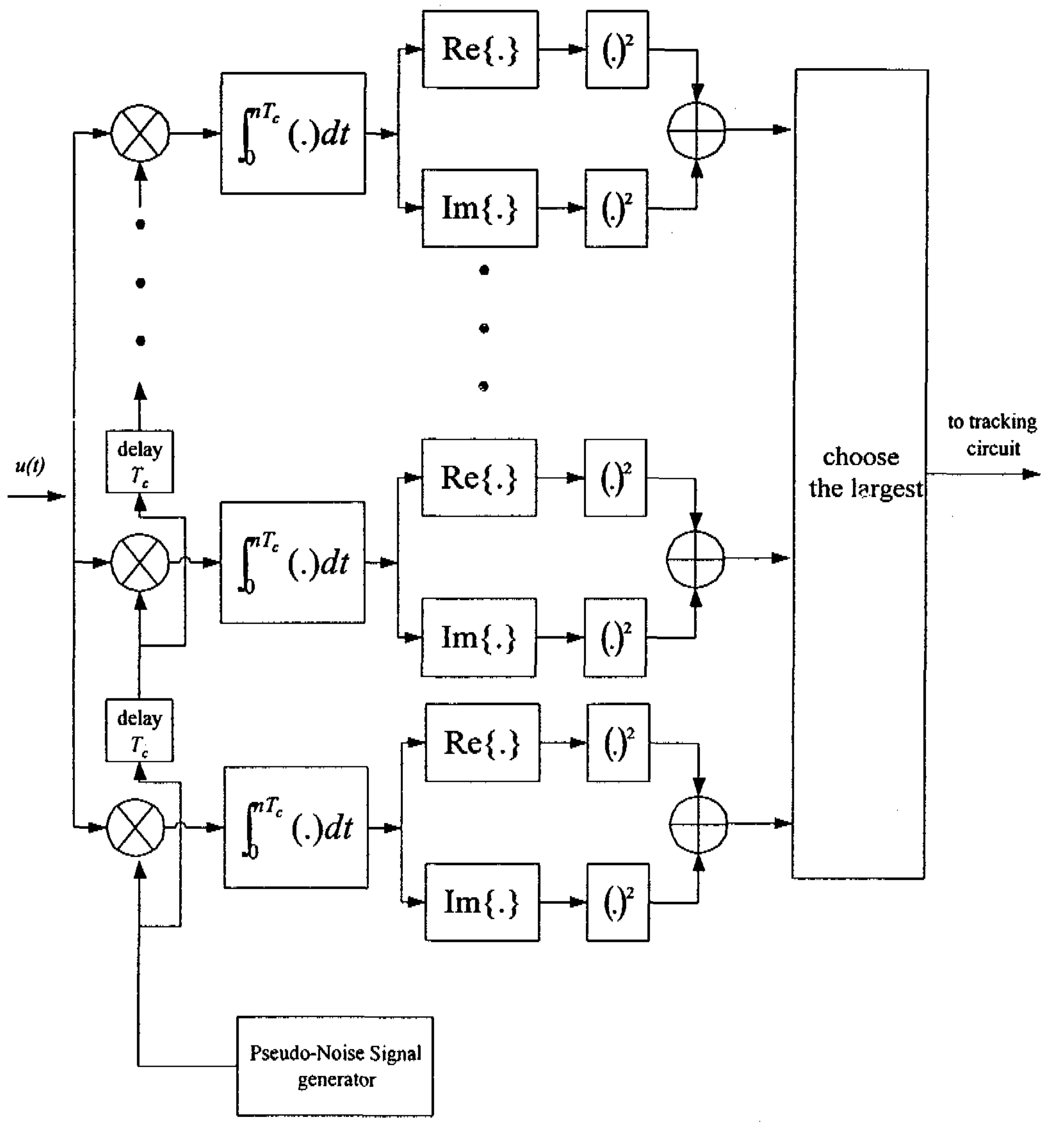


Figure 2.3: A noncoherent parallel search scheme

The second conventional scheme is a parallel search scheme, which is shown in Figure 2.3. The scheme can decrease the acquisition time by using a bank of correlators to correlate the received signal with the local PN signals of various phases. The PN signal phase which corresponds to the highest correlation result will be forwarded to the tracking circuitry. This scheme is very fast but it uses more hardware for implementation. If the period of the PN signal is long, the required hardware can become prohibitive for practical application. To alleviate this problem, hybrid schemes between serial and parallel may be used [27].

The third conventional scheme shown in Figure 2.4 uses the technique of matched filter, which was called PN matched filter (PNMF) [27], where $d_i = \pm 1$ is the value of a PN chip. It is the technique that the incoming signal is convolved with a fixed finite segment of the PN waveform corresponding to $M$ chips and the continuous time output is tested against a threshold to determine when acquisition has occurred. It is very fast technique and uses less hardware for implementation than that of the parallel search scheme. However, if the signal-to-noise ratio is low, $M$ must be increased for satisfactory performance, which increase the hardware, hence it is a trade-off.

The fourth conventional scheme is called "Rapid Acquisition by Sequence Estimation" (RASE) proposed by Ward [33], as shown in Figure 2.5. It bases on a sequential estimation of the shift register states of the PN generator. The receiver loads the local PN generator by the estimated code chips and starts to generate the PN signal. If all of estimated chips are correct, the staring phase of the local PN signal will be correct. It is the fastest PN acquisition scheme at high signal-to-noise ratio. However, the performance of this scheme is poor at low signal-to-noise ratio.

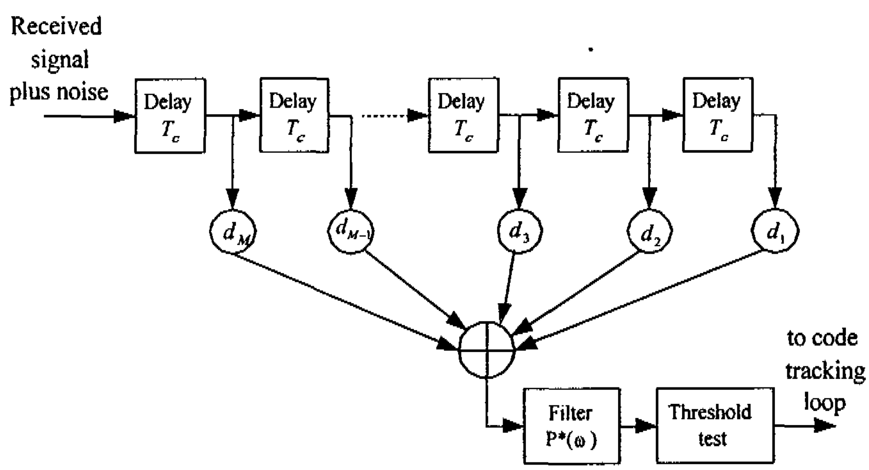


Figure 2.4: A PN acquisition using PN matched filter

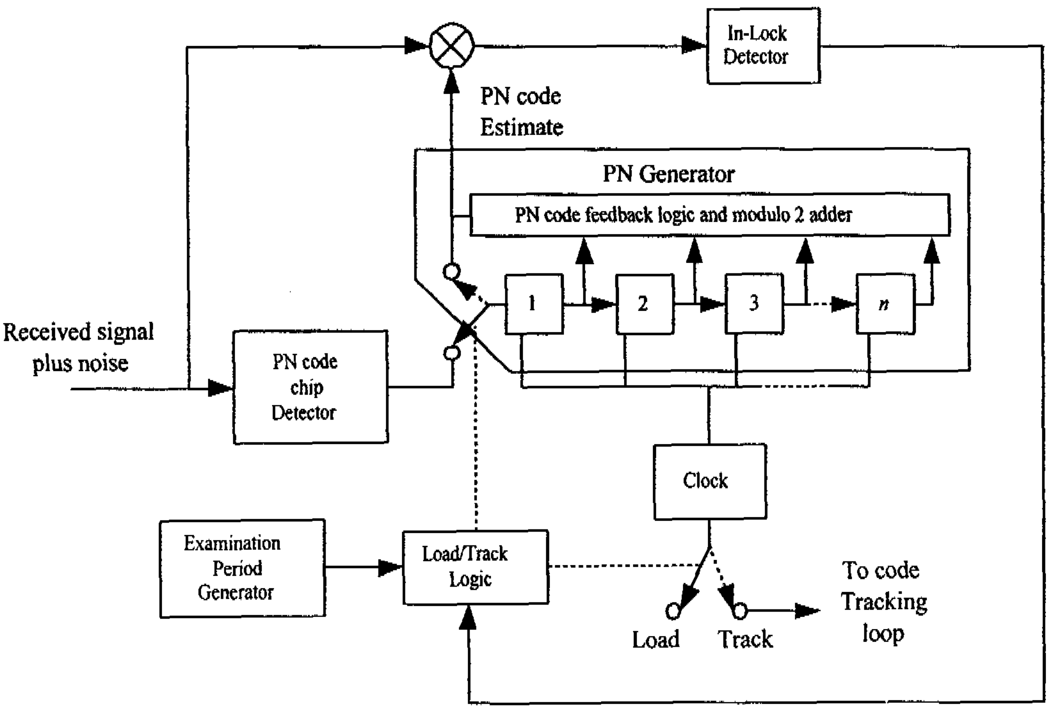


Figure 2.5: A rapid acquisition by sequence estimate

The previous four schemes above are designed on the assumption that there is no prior information of the incoming PN signal phase. When a long PN signal is used, it is very difficult to design PN acquisition scheme to have a good performance without the prior information of the PN signal phase. In these cases, the transmitter should send some information about the PN signal phase to the receiver. One scheme designed on this assumption is called Z search scheme [27]. It uses the correlator to acquire the phase in the same way as the serial search scheme. The difference is the search strategy which searches all possible phases in the forward direction; and if it is not found, the search direction is reversed. The process continues until the correct phase is found.

All of the conventional schemes above can be designed using both noncoherent and coherent detectors. More details of the conventional schemes can be found in [27].

Many reports show the ways to improve and modify the conventional schemes. In the case of serial search scheme, the single-dwell correlator has been modified to use a multiple-dwell correlator. The correlator consists of shorter dwell periods with possible rejection of alignment after each dwell. Therefore the incorrect phase will be rejected in the shorter period of time than is possible with the single-dwell time technique [10][17].

In some situation, acquisition needs to be carried out while the data is being transmitted. Li and Tantaratana [18][19] studied and designed serial search schemes with the presence of data modulation. They presented two practical parallel schemes as approximation to the optimal scheme which are designed with the presence of the data modulation. The numerical results show that performances of these schemes are the same with or without data modulation.

In case of parallel search scheme, Chawla and Sarwate [13] presented four different parallel search schemes. The report shows a way to decrease hardware for implementation.

Because of its fast acquisition time, the matched filter scheme has motivated many researchers to study and improve on this technique. Paul [9] used a surface acoustic wave tapped delay line (SAW TDL) to implement the matched filter. Glisic [14] improved the performance by using automatic decision threshold level control. Su [30] presented performance analyses of four fast acquisition algorithms by employing PN matched filter.

An improvement on RASE was proposed by Chiu and Lee [7]. Their interest in the conventional RASE is that it cannot work well when the data is -1, i.e., the transmitted PN sequence is inverted. However they could not improve the performance when signal-to-noise ratios is small. Barghouthi and Stuber [2] reported a rapid sequence acquisition scheme that uses Kasami sequence instead of the m-sequences. They conclude that their scheme was very effective, and compared well with the performance of parallel scheme.

**2.2 New Acquisition Schemes**

There are several ideas on PN acquisition which are different from the conventional schemes. They can be are summarized as follows.

The first scheme, which was presented by Fair, Wang and Bhargava [12], is a new zero-acquisition time spreading/despreading technique for SS communication systems. This technique does not use the PN synchronization process. It means that the PN synchronization time is equal to zero. It uses the technique which is called Transmitted-Quotient Direct Sequence. It has the same concept as self-synchronization scrambling. A disadvantage of the scheme occurs in the data detection, as shown in the simulation results of [12], which indicated that the BER was higher than those of serial scheme, or matched filter acquisition.

The second scheme is the PN acquisition scheme using a neural network technique which is proposed by Thompson and Dianat [32]. A neural network is used as a noncoherent PN matched filter. The result shows that the neural network has performance close to that of the optimum detector in an AWGN environment. However, this scheme is very difficult to implement.

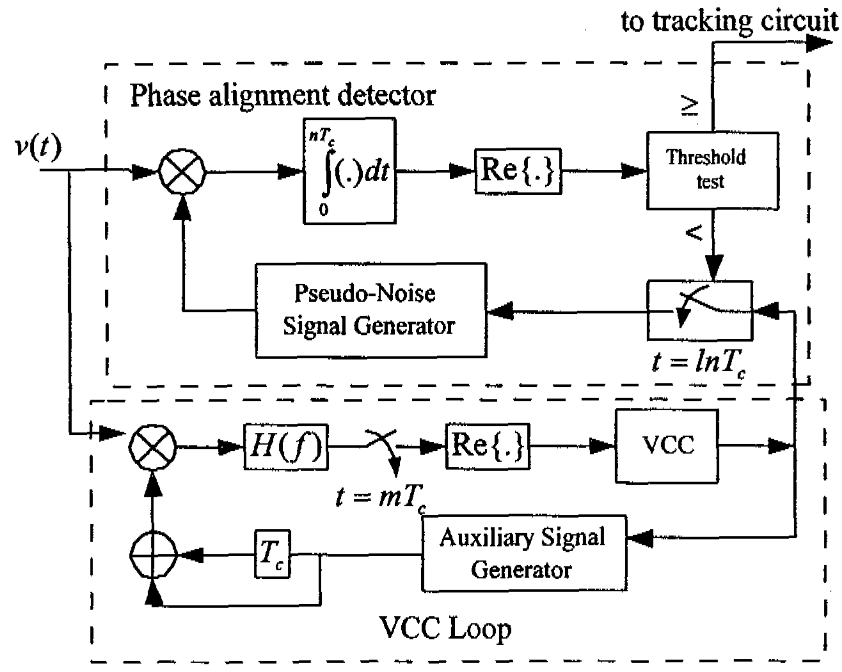


Figure 2.6: A closed-loop coherent PN acquisition scheme for DS/SS systems using an auxiliary signal

Soft synchronization is a new way to synchronize the PN signal which is proposed by Agee, Kleinman and Reed [1, 21]. This technique uses a concept of Fourier-series to regenerate the PN signal at the receiver. The receiver of this technique can detect data during acquisition. However, these papers did not compare the synchronization time with another PN acquisition scheme.

The fourth scheme is a closed-loop PN acquisition scheme using an auxiliary sequence proposed by Salih and Tantaratana [26]. It has a VCC loop which adjusts the phase difference toward zero. In the VCC loop, there is an auxiliary signal which is the key of this scheme. Figure 2.6 shows the block diagram of this scheme

### 2.3 Modeling the PN Acquisition

Performance of a system can be obtained in 3 different ways: actual experiment, computer simulation, and mathematical modeling and analysis. The mathematical modeling and analysis represent the system in a mathematical form which includes all real environment factors. For PN acquisition systems, there are many reports that model and/or analyze the systems.

In 1980, Dicarlo and Weber [10] published a paper that derived a formula for the probability of successful acquisition for the single-dwell serial scheme by utilizing the generating function and presented some numerical results. Using a direct approach, Jovanovic [16] reported statistics of the PN acquisition time of the single-dwell and double-dwell serial scheme. He also extended his technique to Z-search and concluded that the effect of the search strategy on moments of the acquisition time can be isolated from the effect of the detection/verification logic. Chawla and Sarwate [4] used a random sequence model and sequential probability ratio test (SPRT) to derive the probabilities of detection ($P_d$) and false alarm ($P_{fa}$). Madhow and Pursley [20] proposed a two-stage low complexity acquisition scheme for the case of small timing uncertainty which employs a short programmable matched filter for initial acceptance of alignment, followed by a correlator for verification.

Acquisition of PN signal with the presence of data modulation was first studied by Cheng [5]. After that, Cheng, Hurd and Statman [6] presented a PN acquisition with presence of data modulation and Doppler shift. Li and Tantaratana [18][19] also studied the PN acquisition in this case and proposed PN acquisition schemes to eliminate the effect of data modulation

In a mobile phone system, there is a problem of fading channel. Sourour and Gupta [28] analyzed this effect which occurs on both parallel and serial matched filters and concluded that the improvement of the parallel system over the serial system reaches up to 4-5 dB. Another work which studied the system on fading can be found in [15][29][31]. While, Fuxjaeger and Iltis [13] developed analytical techniques for evaluating the mean and variance of an acquisition time when code Doppler is present, and evaluated the performance of a two-dwell correlator system.

An interesting result was proposed by Chung, Chien, Samulei and Jain [8]. It analyzed a real implementation of an all-digital BPSK DS/SS receiver. In this work, they used the serial single-dwell search scheme because of it ease in implementation.

In conclusion, there are three main issues which need to be considered in designing an acquisition scheme:

1) the cost of hardware

2) acquisition time

3) performance, especially at low signal-to-noise ratio where a DS/SS operates.