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Adaptative acquisition of code PN in CD-CDMA systems with CA-CFAR

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defended le 01 /10 /2020 in front of the jury composed of :

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Acquisition adaptative du code PN dans Les systèmes DS-CDAMA avec CA-CFAR

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Dedications

I dedicate this work

*To my family especially my loving parents, my sisters "**AMINA** and **MARIA**" and my brother **DJAMEL** and my **cousins** for their support and their love without them I could not reach what I have become now.*

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Dedications

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Abstract

DS-CDMA is a combination of two important technologies in telecommunication history: CDMA which allows multiple users to have a unique code each and direct sequence spread spectrum which is one of the most used forms of spreading bandwidthes.

DS-CDMA requires mainly synchronization between the transmitter and the receiver to fully receive useful data. In other hand, the receiver must be synchronized with a locally generated Pseudonoise (PN) code. In addition, due to environment condition change an adaptive CFAR detector is added to our system to solve problems in acquiring PN sequences and to combat the variability and instability of detection and false alarm probabilities. The problem is therefore the following: how to acquire the pseudonoise (PN) code in a DS-CDMA system associated with a CFAR detector?

Key words: DS-CDMA, CA-CFAR, pseudonoise, probability of detection, false alarm.

Résumé

DS-CDMA est une combinaison de deux technologies importantes dans l'histoire des télécommunications: CDMA qui permet à plusieurs utilisateurs d'avoir un code unique pour chacun et un spectre étalé à séquence directe qui est l'une des formes les plus utilisées d'étalement des bandes passantes.

DS-CDMA nécessite principalement une synchronisation entre l'émetteur et le récepteur pour recevoir pleinement des données utiles. D'autre part, le récepteur doit être synchronisé avec un code de pseudo-noise (PN) généré localement. De plus, en raison du changement des conditions de l'environnement, un détecteur CFAR adaptatif est ajouté à notre système pour résoudre les problèmes d'acquisition de séquences PN et pour lutter contre la variabilité et l'instabilité des probabilités de détection et de fausses alarmes. Le problème est donc le suivant: comment acquérir le code pseudo-bruit (PN) dans un système DS-CDMA associé à un détecteur CFAR?

Mots clés: DS-CDMA, CA-CFAR, pseudonoise, probabilité de détection, fausse alarme.

الملخص

DS-CDMA عبارة عن دمج تقنيتين مهمتين في تاريخ الاتصالات اللاسلكية CDMA : الذي يسمح للعديد من المستخدمين بالحصول على رمز فريد لكل منهم وطيف انتشار مباشر للتسلسل الذي يعد أحد أكثر أشكال عرض النطاق الترددي استخدامًا.

يتطلب DS-CDMA بشكل أساسي التزامن بين المرسل والمستقبل لتلقي البيانات المفيدة بالكامل. من ناحية أخرى ، يجب مزامنة جهاز الاستقبال مع رمز (PN) الذي تم إنشاؤه محليًا. بالإضافة إلى ذلك ، نظرًا لتغير ظروف البيئة ، تمت إضافة كاشف CFAR التكيفي إلى نظامنا لحل مشكلة الحصول على تسلسل PN ولمكافحة تنوع وعدم استقرار الكشف واحتمالات الإنذار الخاطئ. وبالتالي فإن المشكلة تكمن في ما يلي: كيفية الحصول على الكود (PN) في نظام DS-CDMA المرتبط بكاشفCFAR ؟

الكلمات المفتاحية: التسلسل المباشر- وصول متعدد بتقسيم الكود, متوسط الخلية-معدل انذار كاذب ثابت, ضوضاء زائفة, احتمالية الكشف, انذار كاذب.

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LIST OF ABBREVIATIONS AND SYMBOLS

AWGN:	Additive White Gaussian Noise
BPSK:	Bi Phase-shift Keying (2PSK)
CA-CFAR:	Cell Averaging Constant False Alarm Rate
CDMA:	Code Division Multiple Access
CFAR:	Constant False Alarm Rate
CUT:	Cell Under Test
DS-CDMA:	Direct Sequence Code Division Multiple Access
DSSS :	Direct Sequence Spread Spectrum
FDMA:	Frequency Division Multiple Access
FFH-CDMA:	Fast Frequency Hopping Code Division Multiple Access
FHSS:	Frequency Hopping Spread Spectrum
GO-CFAR:	Greatest Of Constant False Alarm Rate
GSM:	Global System for Mobile Communications
GPS:	Global Positioning System
H_0:	Hypothesis designating the absence of the target signal
H_1:	Hypothesis designating the presence of the target signal
LFSR:	Linear feedback Shift Registers
MAI:	Multiple Access Interference
PDF:	Probability Density Function
P_d:	Probability of Detection
P_{fa}:	Probability of False Alarm
P_m:	Probability of non-detection
PN:	Pseudonoise
P_{nfa}:	Probability of Non False Alarm
SFH-CDMA:	Slow Frequency Hopping Code Division Multiple Access
SNR:	Signal to Noise Ratio
SO-CFAR:	Smallest Of Constant False Alarm Rate
T:	Threshold

TDMA:	Time Division Multiple Access
W-CDMA:	Wideband Code Division Multiple Access
WLAN:	Wireless Local Area Network

General introduction

The field of telecommunications, which has become one of the essential pillars of daily life, is growing intensively. Consumption is increased over time due to the increased need of the individual and the number of users. Even the type of data sent is on multiple forms.

So that the connection is established on several kilometers, the wiring is no longer welcome. On the other hand, we have to use the wireless connection with its various new technologies and difficulties to meet consumer demands without giving up on old ones.

The networks to which each part of the world is connected are extremely numerous and diverse. Some are established using multiple access techniques for accessing support such as time division multiple access (TDMA) and frequency division multiple access (FDMA).

For wireless broadband transmission systems, code division multiple access technique is used. Developed in the 1980s for satellite communications and first used by military services, CDMA consists of spreading the spectrum according to a PN sequence code. The receiver uses the same code to demodulate the signal and extract the useful information.

The obstacle manifests itself in the phase of code acquisition where it is difficult to obtain the spread spectrum. The objective of this thesis is to make a study on code synchronization in a DS-CDMA type extended spectrum communication associated with a CA-CFAR detector for the acquisition of the Pseudo-Noise code.

This thesis is subdivided into three chapters:

The first chapter will firstly present the most used multiple access techniques, then we explain the principle of spread spectrum and its techniques. Additionally, we discuss direct sequence spread spectrum in CDMA systems. Finally, synchronization of DS-CDMA systems is briefly explained.

The second chapter starts with the explanation of the code acquisition and its two phases: initial code acquisition and code tracking. Then, research strategies are presented followed by detector techniques. Finally, fixed and adaptive threshold detector are pointed out.

In the third chapter, we first mention the adaptive threshold acquisition principle in general. After that, we explain the process of CFAR detection followed by CFAR detector types mainly discussed CA-CFAR and its methods. Finally, we simulate our results for different variables

CHAPTER I

STATE OF THE ART

Summary :

I.1 INTRODUCTION.
I.2 MULTIPLEXING TECHNIQUE.
I.3 SPREAD SPECTRUM
I.4 SYNCHRONIZATION IN DS-CDMA SYSTEMS.
I.5 CONCLUSION.

I.1 Introduction:

The Development of digital communication systems and the increasing of number of users means the augmentation of information transfer request and in the number of simultaneous accesses to the transmission channel. Different multiple access techniques had appeared to optimize the use of available frequency resources in order to increase the capacity of the networks. In this chapter, we present multiple access techniques with their types and characteristics (FDMA, TDMA, and CDMA).

To allow multiple users to access the network simultaneously, and for more confidentiality, great interest has been focused on the multiple access technique with code distribution CDMA, this technique is combined with direct sequence spread spectrum (DSSS) modulation to achieve DS-CDMA direct sequence code division multiple access. This technique had some difficulties, which we will present it in this chapter.

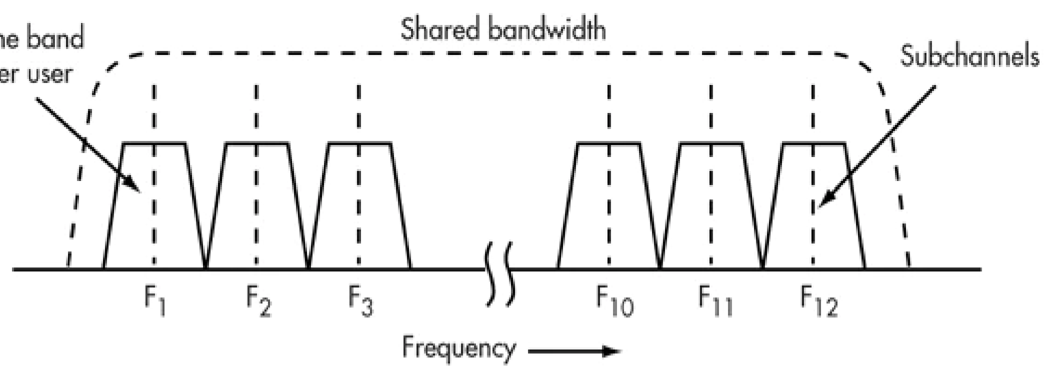
I.2. Multiplexing techniques:

Multiplexing is a technique that allows many users to exchange data simultaneously by sharing one transmission medium.in order to optimize the capacity of digital communication system networks, three principal types of multiple access techniques have appeared:

- **FDMA**: Frequency Division Multiple Access.
- **TDMA**: Time Division Multiple Access.
- **CDMA** : Code Division Multiple Access.

I.2.1 Frequency Division Multiple Access:

The principle of multiple access by frequency division is to distribute the bandwidth available between different users[1] as illustrated in (**FigureI.1**). So all users can transmit simultaneously theirs data by using different sub-bandwidth.



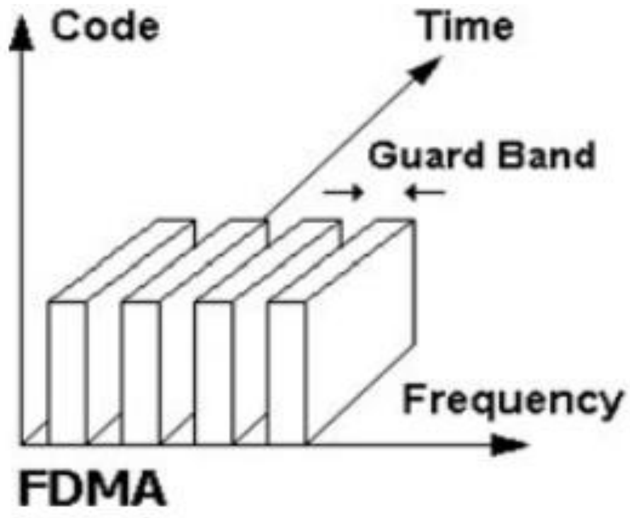


Figure.I.1 FDMA multiple access technique.

Advantages:

- Reduction in symbol rate.
- Simple maintaining with propre filters due to isolation between channels.
- No tight synchronism between users is required.

Disadvantages :

- Steady Frequency .
- Expensive duplexers.
- To avoide interference between sub-bands, we separate the bands by a guard band.these guard band degrade the spectral efficiency of FDMA systems.

I.2.2 Time Division Multiple Access:

The second major type of multiplexing technic TDMA largely is used in digital communications systems such as GSM (Global System for Mobile communication).

The principal of TDMA is to divide the bandwidth into time frames .frames are divided into smaller fixed periods called “time slot” which are occupied by different users as illustrated in (**Figure.I.2)**. Each user can access to the entire channel and transmit their data but only when it’s their turn[1].

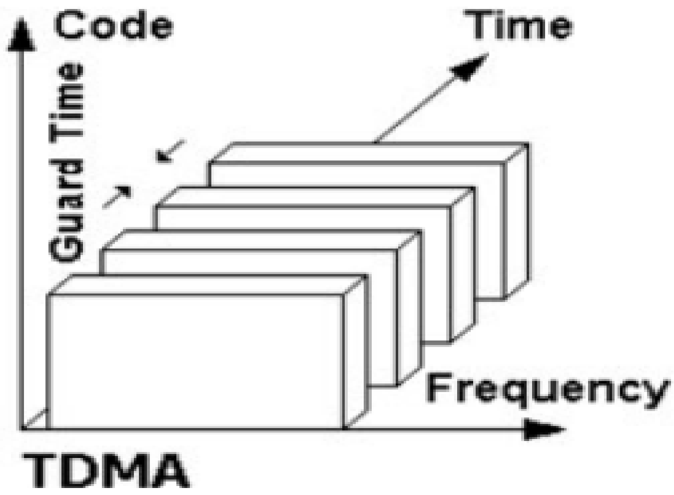


Figure.1.3. TDMA multiple access technique.

Advantages:

- Diversity frequency.
- Separate users according to time, it ensures that there will be no interferences.
- Duplexers are not required.
- Absence of frequency guard band.

Disadvantages:

- Multipath interferences affect the quality of signal.
- Existence of time guard band.

I.2.3 Code Division Multiple Access:

Code division multiple access, or CDMA, is a multiplexing technique defined as spread spectrum that assign each user a unique code or sequence [1].

In CDMA systems, channels are defined not by time or frequency but by code which means all CDMA users share the same frequency band and transmit their data in the same time as illustrated in **Figure.I.4.**
Generally we find two type of CDMA[2] :

- **FH-CDMA (Frequency Hopping-CDMA):**
  In CDMA frequency hopping the data transmitted on different frequencies which change periodically, this change is indicated by the spreading code. There are two types of CDMA frequency hopping:

-SFH-CDMA: Slow Frequency Hopping-CDMA : when several sequences of codes are transmitted at the same frequency.

-FFH-CDMA: Fast Frequency Hopping-CDMA: when the chips of the same code are transmitted on several frequencies.

- **DS-CDMA (Direct Sequence-CDMA):**
  In CDMA direct sequence the data is coded directly.

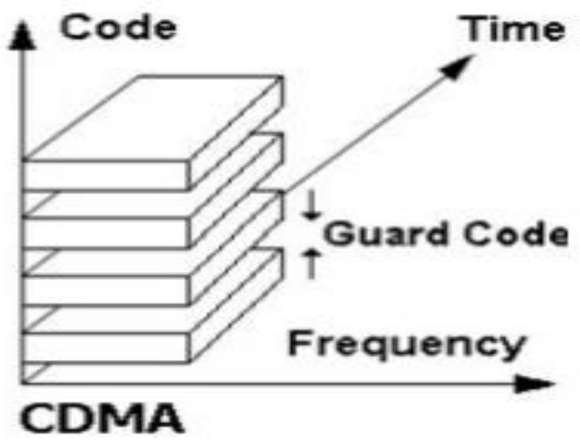


Figure.I.4. CDMA multiple Access technique.

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Applications:

CDMA can system can be used in many sectors, we can cite some here:

- CDMA is ideally suited for military applications because of its safety and noise immunity.
- CDMA is used for wireless systems with a fixed base station and many mobile stations at varying distances.
- CDMA is used in digital cellular telephone services because it allows more users to occupy a given frequency band.
- CDMA is used in satellite communication systems so that many signals can use a transponder, which makes it more efficient.
- CDMA is used in the field of geolocation (GPS or Galileo system).
- CDMA is used in optical communications to establish the initial synchronization between the transmitter and the receiver.
- In addition, W-CDMA (Wideband-CDMA) technology is used for digital cellular telephone systems to enable voice transmission, as well as high-speed data, fax and Internet communications.

Advantages:

There are certain properties that made CDMA useful :

- The possibility of transmitting asynchronously without waiting for the transmission medium to be free.

- CDMA offers excellent protection against noise, interference and hacking, resistance to damage due to multiple paths, soft handoff.
- Significant flexibility than the other two techniques (TDMA and FDMA).
- CDMA offers Frequency diversity that considerably reduces performance degradation in a selective fading channel in frequency.

In addition, CDMA can offer:

- Wide coverage.
- Better management of available resources.
- Very good frequency reuse efficiency.
- Very good transmission efficiency.

Disadvantages:

However, the large number of advantages CDMA can offer, this technique has some disadvantages, we can cite:

- Near-far effect, which require strict control of the power of the transmitted signals.
- As the number of users increases, the quality of service decreases.
- Low yield.

I.3 Spread Spectrum:

I.3.1 Spread Spectrum principle:

Spread spectrum is a technique developed historically for encryption to secure communication. A signal spread by an adapted technique cannot be identified by scanning frequencies, it cannot be scrambled by the emission of a message which would interfere, and moreover is confused with the "natural" noise of a transmission (if a spreading technique based on PN sequences is used) [8] as shown in **Figure.I.5**. This technique is generally used in CDMA systems so it can accomplish their multiple-access capability.

In SS communication, the data occupies a bandwidth in excess of the minimum bandwidth necessary to transmit the data. Spectrum spreading is accomplished by codes that are independent of data. Same code is used at the receiver to dispread the received signal so that the original data maybe recovered.

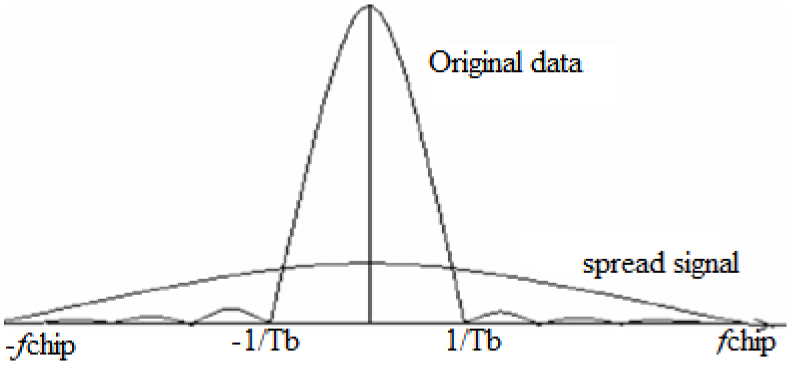


Figure.I.5 spread spectrum concept.

Spread-spectrum is given in the Shannon and Hartley channel-capacity theorem:

$$C = B \times \log_2 (1 + S/N) \qquad (I.1)$$

With : C : the maximum channel capacity in bits per second (bps).

B: the required channel bandwidth in Hz.

S: the signal power emitted in watt (W).

N: the noise power in watt (W).

In this equation, we can rise the capacity C by changing the bandwidth or by changing the signal/noise power ratio in a logarithmic way.

Advantages:

- Higher treatment gain.
- Possibility to transmit broadband service.
- Security (use in military).

Disadvantages:

- Precise Synchronization time (any delay that can cause interference noise).
- Interferences between users.

I.3.2 Spread spectrum techniques:

Two spread spectrum techniques are widely used to provide reliable communications:

- ✓ Direct sequence spread spectrum (DS-SS) is a technique also called direct coding in which a signal is transmitted over a bandwidth considerably higher than the frequency content of the original information by structuring the signal using a direct sequence.
- ✓ Frequency hopping spread spectrum (FH-SS) which is based on variation of the Pseudo-random discrete hop transmission frequency.

From the technical specifications of certain standards, we can summarize in **table I.1** their specificities and their similarities:

Standard	**Bandwidth (MHZ)**	**Bit rate (bps)**	**Access technique**	**Spread factor**
IS-95	824-849 869-894	1.2288M	DS-CDMA	256
BLEUTOOTH	2400-2483.5	1M	FH-CDMA	79
UMTS	1900-2025 2110-2200	3.84M	DS-CDMA	4,8,…..,256
CDMA2000	824-849 869-894	1.22883M 3.6864M	DS-CDMA	4,8,….128 4,8,….256
WLAN	2400-2484	11M	DS-CDMA	13
ZIGBEE	868-868.6 902-928 2400-2483.5	20k 40k 250k	DS-CDMA	1 10 16

Table I.1 Characteristics of some telecommunication standards.

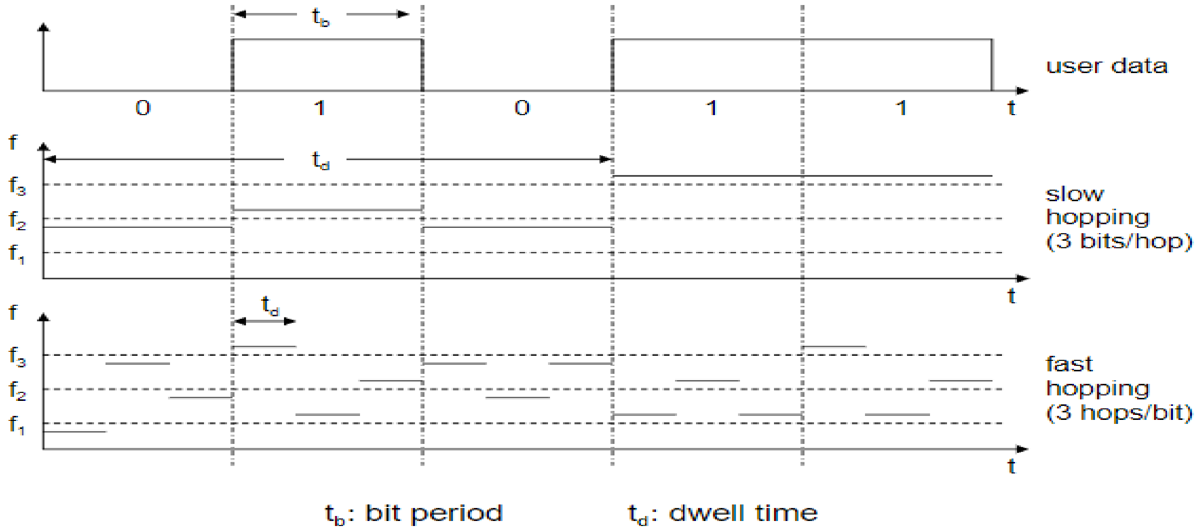
Table I.1 shows that DS-CDMA is most dominant technique in telecommunications systems.

I.3.3 Frequency hopping spread spectrum CDMA system:

FHSS is a technique based on transmitting radio signals by switching of frequencies during the transmission process using a pseudo-random sequence known by both the transmitter and the receiver, which will exchange their operating frequencies after each transmission of a short burst of data. It is used extensively in military applications to avoid eavesdropping and interference[5].

There are two version of FHSS systems:

- ✓ Fast frequency hopping system where a short burst of the data is transmitted for the duration between carrier hops. Therefore, for a bit system, the frequency hopping rate may be higher than the data bit rate.
- ✓ Slow frequency hopping system: where more than one data symbol is transmitted in the interval between frequency hops.



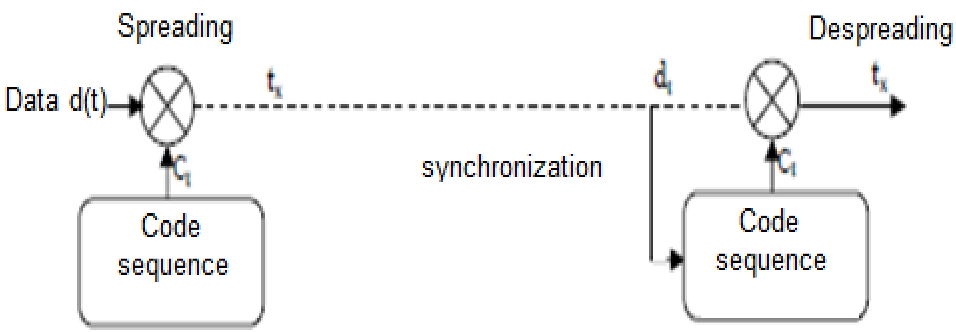
FigureI.6 Example of time–frequency plot for slow and fast hopping.

FigureI.6 shows the deference between slow and fast frequency hopping during a dwell time, which is the time spent on a channel with a certain frequency.

I.3.4 Direct Sequence spread spectrum CDMA system :

Nowadays, DS-SS is considered to be one of the most used forms of spread spectrum. It spreads the bandwidth by multiplying each informative symbol by a completely pseudo-random sequence directly. This pseudo random sequence contains the elements or chips, which have a Tc period (chip period) much, lower than Ts (time symbol) which causes an increase in bandwidth [5].

DS-CDMA systems require two pseudo-random sequence generators, which are defined to generate pseudorandom sequence used for spreading at the transmitter and dispreading at the receiver as illustrated in **figure I.7**.



FigureI.7 Direct sequence spread spectrum modulation system.

I.3.4.1 Transmission Side (Modulation):

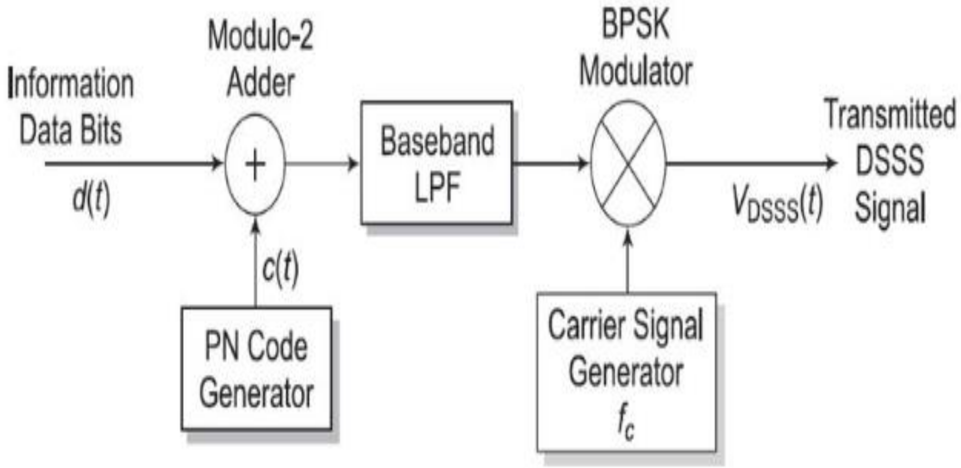


Fig1.7 DSSS modulation system with BPSK carrier.

Modulo-2 adder (**Exclusive or**) is the equivalent of a binary signal's multiplication.

- At the first stage :the baseband binary data d(t) is multiplied directly by a code sequence that is produced by a pseudo-noise generator to obtain the spreading power:

$$S(t)=d(t)*C(t) \quad (I.2)$$

- At the second stage : the signal S(t) is transmitted to a baseband low-pass filter to limit the bandwidth's energy, the signal resulting is modulated in BPSK with a radian frequency $2\pi f_c$ and a phase shift modulation $\theta(t)$:

$$V(t)=S(t)*\cos [2\pi f_c\, t+ \theta(t)] \quad (I.3)$$

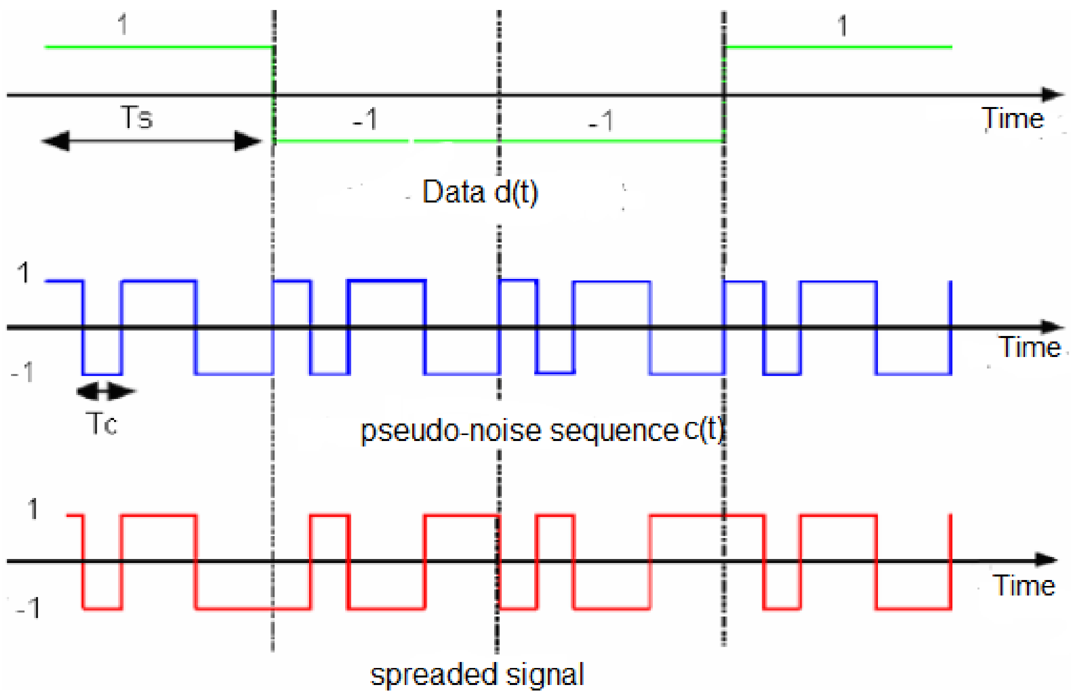


Figure I.8 Spreading spectrum principle**.**

Figure I.8 shows a signal before and after spreading the spectrum in which the duration of the sequence is equal to the symbol period.

I.3.4.2 Reception Side (Demodulation):

At the reception, the opposite operations are performed as shown in **Figure 1.9**

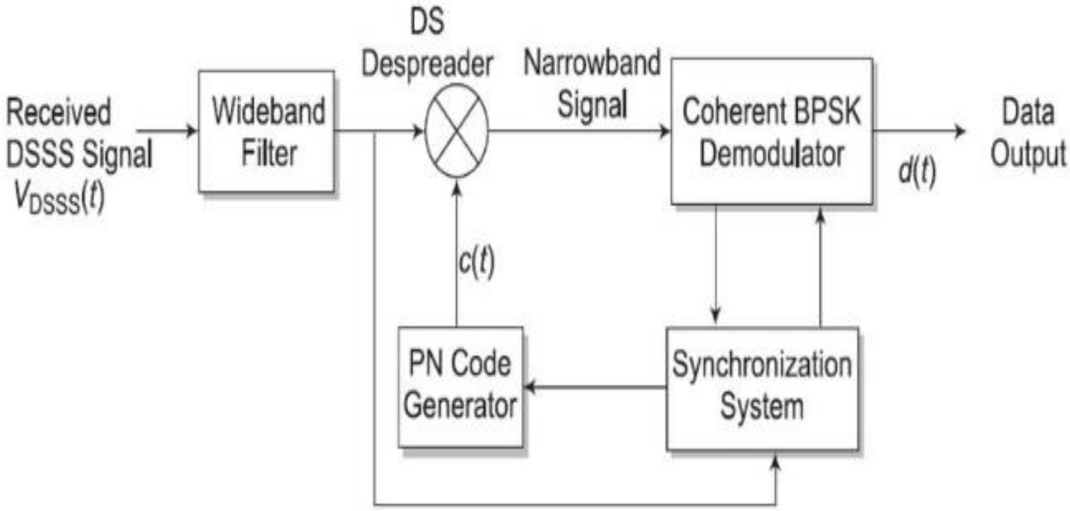


Figure1.9 DS Despreader system with coherent BPSK Demodulator.

- At the first stage, the signal V(t) is down-converted to baseband using a wideband filter.
- At the second stage: after a correct synchronization, V(t) is multiplied by a locally produced phase copy of the transmitted code sequence.by this multiplication the PN code is removed from the signal.
- Finally: the signal V (t) is despread and passed to a BSPK demodulator. We hence find, in theory, the baseband signal d(t). This signal is also added with a bandpass AWGN which stands for (Additive White Gaussian Noise) as shown in equation **(I.4).**

$$A(t)=d(t)+n(t) \qquad (I.4)$$

The receiver must decide, at every Ts (time symbol), duration of an information bit, whether a 1 or a 0 has been transmitted.

The recovered information A(t) thanks to demodulation system can only be obtained if the local PN code is matched with the received code. This function is provided by the synchronization system of the receiver which is made up of the Acquisition and Tracking modules.

I.3.5 spreading code:

In a standard DSSS system, the data to be transmitted is multiplied by a pseudo-random sequence (PN), usually produced by a Linear Shift Feedback Register (LSFR). Therefor, the choice of spreading code plays an important role in the DS-CDMA system[2].

The main criteria for selecting a particular set of user signature sequences in CDMA applications are that the number of possible different sequences in the set for any sequence length should be high, in order to accommodate a large number of users in a cell. The spreading sequences should also exhibit low cross correlations to reduce multiuser interference. High peak correlation is also required, to minimize the probability of false alarms, during code acquisition.

I.3.5.1 Pseudo-random sequences:

At the end of the transmission, a pseudo-random noise (PN) sequence is mixed with a digital data. To improve the synchronization of the sequences on reception, linear generators are generally used which produce sequences of periodic lengths determined by the parameters of the generators.

Autocorrelation's function is given by:

$$R_c=\int_{-\infty}^{+\infty} c(t)c(t-\tau)dt = 0 \text{ ; with } \tau \neq 0 \qquad (I.5)$$

I.3.5.2 Maximum length sequence:

Maximum length PN sequences are binary sequence generators capable of outputting all possible combinations of 2m-1 cyclic shifted binary sequences, where m is the size of the Linear feedback Shift Registers (LFSR)registers used to generate such sequences. Terms such as pseudo-random binary sequences (PRBS) or pseudo-noise sequences are also used to denote m-sequences. To generate an m-sequence, the return connection of the LFSRs is connected according to a primitive polynomial.

In m-sequence no value in the sequence can be deduced from the others, the auto-correlation function is similar to δ (n) and the cross-correlation between two PN sequences is zero. also, a cycle is defined as a set of identical symbols so the length of the sequence is equal to the number of these symbols in the sequence.

I.3.5.2 Gold sequence:

Gold Sequence Generators are a class of pseudo-random binary generators which have better properties than previous generators to reduce the multiple access noise[8]. They are composed of two generators of maximum length sequences that form a preferred pair.

The generic equation that gives the binary value at the output of the generator is:

$$C_m=\sum_{i=1}^{N} C_{ai}\, a_{m-i}+\sum_{i=1}^{N} C_{bi}\, b_{m-i} \qquad (I.6)$$

Where

-a_m and b_m are the outputs of the registers.

-C_{ai} and C_{bi} are the coefficients.

-N the length of the registers $N=2^n-1$.

Gold's sequence is considered to be one of the best sequences offered, so the cross-correlation takes only three possible values (-1,-t or t-2).

I.4 Synchronization of DS-CDMA systems:

To recover the informative signal, the receiver must be perfectly synchronized with the transmitter, which means that the code in the receiver station is exactly aligned with that of the transmitter station. This operation is carried out in two stages:

- Initial synchronization or acquisition: it is the most important and difficult task.it synchronized the code received and the code generated locally with certain precision.
- The pursuit of the code or Tracking: it is a simple task to accomplish, allows executing and maintaining the synchronization between the transmitter and the receiver.

I.4.1 Acquisition:

Acquisition is the process by which the received signal is aligned with the local PN code usually within a fraction of a chip. Usually, a known sequence is sent by the transmitter to allow the receiver to acquire the signal before the start of demodulation.

I.4.2 Tracking:

Once the acquisition is completed, the tracking phase is activated. The signal is aligned to a fraction of a chip with the local PN code. The tracking module takes over to align these two signals more precisely and to compensate for clock drift if necessary. The acquisition must be done correctly, if the synchronization is lost, the receiver can return to the acquisition phase and then return to the pursuit.

I.5 Conclusion:

In this chapter, we have presented the three main multiplexing techniques used in mobile radio systems, FDMA, TDMA and CDMA, then we explained the concept of spread spectrum with the presentation of the most used methods in this system DS-SS. We have also seen that in order to recover the transmitted signal, there should be a synchronization between the PN code generated locally and the PN sequence of the received signal. This operation is accomplished with two steps: code acquisition and tracking which will be discussed in more details in the next chapter.

CHAPTER II

PN code synchronization

Summary :

II.1 INTRODUCTION.
II.2 CODE ACQUISITION.
II.3 RESEARCH STRATEGIES.
II.4 DETECTOR TECHNIQUES.
II.5 CONCLUSION.

II.1 Introduction:

Nowadays, the delayed information is considered as a big problem especially for important businesses such as in the military field. For the communication to be established, the transmitter and receiver should be in synchronization.

In this chapter, we will be discussing code acquisition that was briefly mentioned in the previous chapter, the problem of initial synchronization also viewed as an attempt to synchronize the receiver clock to the transmitter clock. Next, we shall consider talking about the search strategies and the detector structure.

II.2 Code acquisition:

Receiving useful data is possible only after a receiver synchronizes the locally generated PN sequence with the received PN sequence. Thus, the pseudonoise (PN) code synchronizer is a fundamental element.

The attempt to synchronize the receiver clock to the transmitter clock is considered to be the initial synchronization problem. For a DS-SS system, if a chip duration is missing, the process of dispreading the spread spectrum signal may be impossible considering the spreading spectrum has a small out-off-phase. Essentially, to implement any form of spread spectrum technique, the timing of the transmitted spread spectrum signal is required.

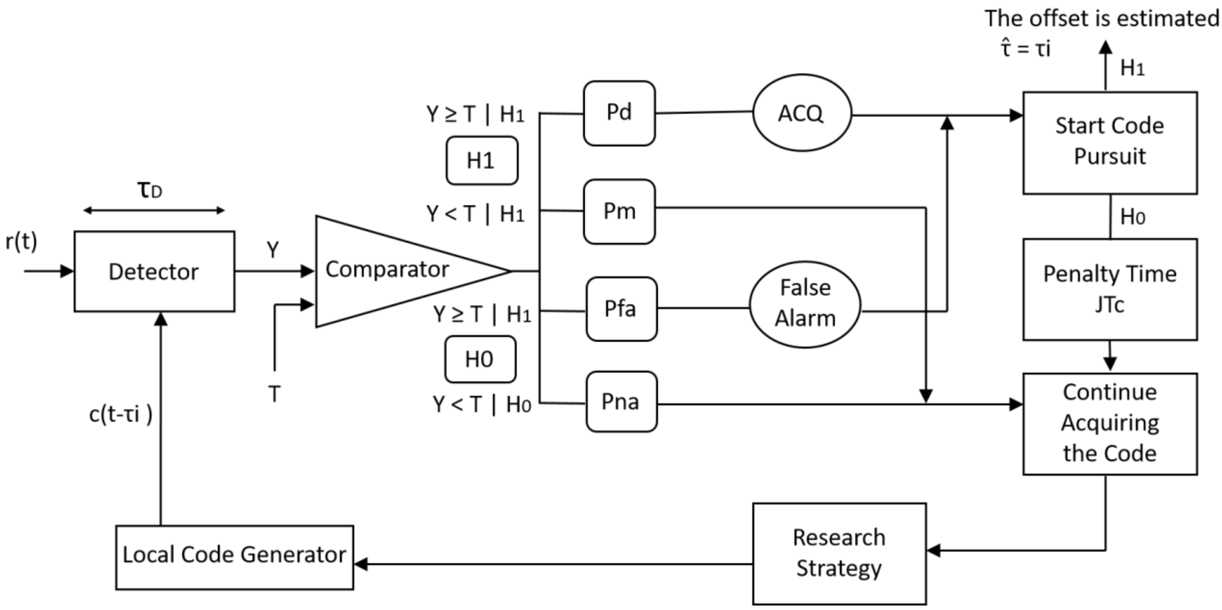
There is always an initial timing uncertainty that is due to propagation delay in the received signal, even though quite accurate and stable clocks are commonly used in SS systems to reduce the time uncertainty between the receiver clock and the transmitter clock.

Two steps are usually acquired to achieve code acquisition:

- Acquisition for coarse code alignment: which synchronizes the transmitter and receiver to within an uncertainty of a chip period.
- Code tracking: which performs and maintains fine synchronization between the transmitter and receiver.

II.2.1 Initial code acquisition phase :

The purpose of the acquisition is to synchronize the locally generated code with the receiver and the received code. The receiver accepts a phase proposed by hypothesis for the spreading sequence and attempts to dispread the signal received by this same phase. If the proposed phase matches the sequence of the received signal, the broadband signal will be correctly dispread and will give the original narrowband information. A band pass filter with a bandwidth similar to that of the narrowband signal is then used to recover energy. In this case, the receiver decides that an approximate synchronization is finished; and activate the tracking loop to perform fine synchronization. Otherwise, that is to say that if the proposed phase is different from that of the received signal, the bandpass filter will recover only a small part of the energy. The receiver then decides that the proposed phase is incorrect ad tries again with other phases[3].



H_1: codes are synchronized

H_0: codes are not synchronized

P_d: probability of detection

P_m: probability of non-detection

P_{fa}: probability of false alarm

P_{nfa}: probability of non-false alarm

τ_D: the observation time

T: the threshold

Figure II.1 General acquisition circuit [4].

II.2.2 Code tracking phase:

The transmitter and the receiver are in motion relative to each other, which requires maintaining synchronization over time. For this, we use a code tracking loops, the simplest example of which are Delay Locked Loops (DLL) in baseband. These loops operate analogously to phase locked loops (PLL) when they use to synchronize to a sinusoidal signal. This type of loop assumes that we have previously demodulated the received signal so as to recover only the code used for spectral spreading[6]. We note the signal resulting from this demodulation:

$$S(t)=\sqrt{2P0}\ c(t-\tau) + n(t) \qquad (II.1)$$

Where c (t) is the spreading code.

We correlate S (t) with a code "slightly" in advance (i.e, Ahead of less than half a chip) $c\left(t+\tau+\frac{Tc}{2}\right)$ and with a code slightly in delay $c\left(t+\ \tau-\frac{Tc}{2}\right)$ (as shown in **Figure II.2**).

Then we calculate the average temporal on a block of code of the difference between these two correlations, that is to say that we extract the continuous component. This average is positive if you are early and negative if you are late, which allows to adjust the phase.

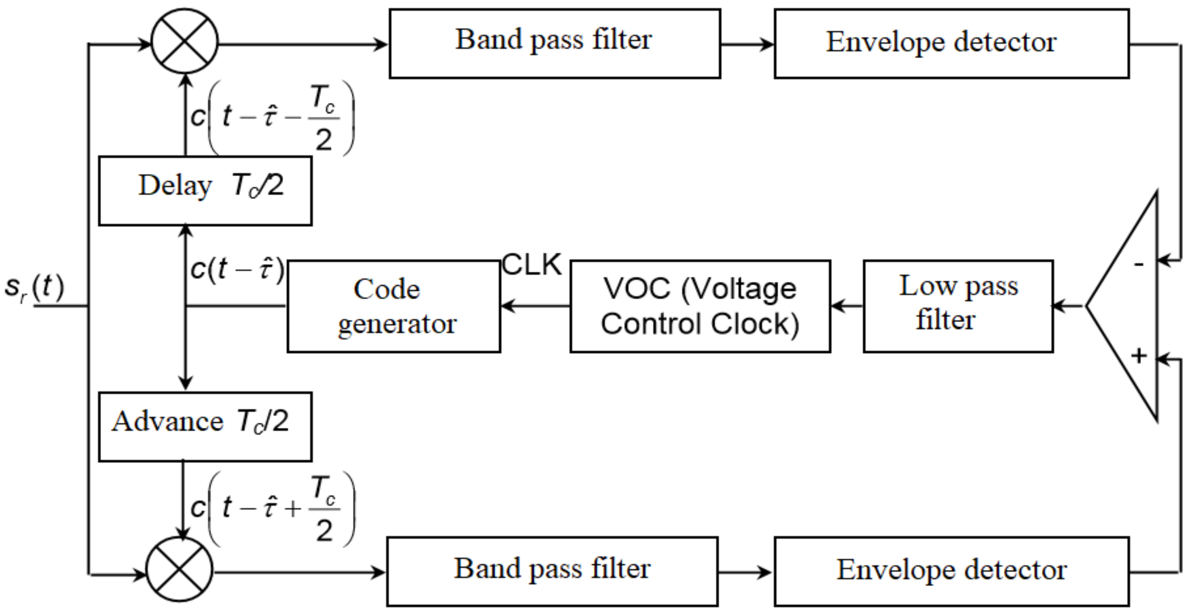


Figure II.2 Block diagram of a DLL tracking loop [4].

II.3 Research strategies:

The search strategy is the manner by which the receiver searches through the uncertainty region. This sweep can be carried out continuously or in discrete steps. The time uncertainty region is usually quantized into a finite number of elements (cells), through which the receiver is stepped. Which particular search strategy is selected by the receiver is dependent on the nature of the uncertainty region, available prior information, statistical quality of the tests performed, availability of stepping and rewinding mechanisms, etc. for more description of the different search strategies. Code Acquisition search schemes can be classified as serial, parallel or hybrid strategies.

II.3.1 Serial search:

The first strategy that we consider is serial search. In this method, the acquisition circuit pursuit possible phases and test them until a correct alignment phase is detected[8]. The detector output is compared with a threshold through a repeated process as shown in **Figure II.3**.

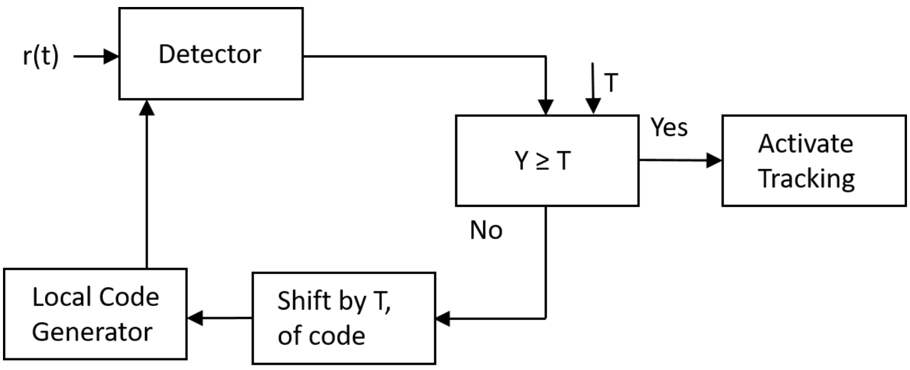
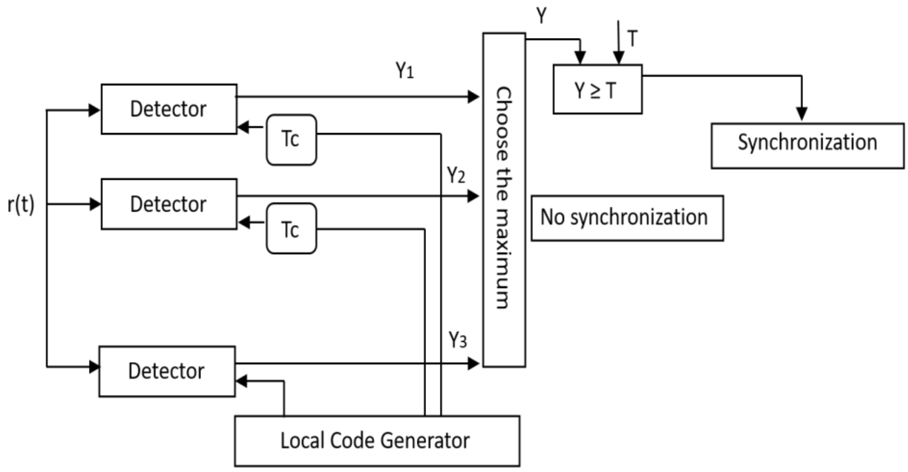


Figure II.3 Principle of serial acquisition [4].

The serial search technique is a common used strategy, as it is known to be economically advantageous. In addition, the circuit for serial search is not complex. However, penalty time is large. Therefor we have to choose a longer dwell time so we can degrade the miss probability. This means a large acquisition time (i.e., slow acquisition).

II.3.2 Parallel search:

In a parallel acquisition system, the code acquisition time can be significantly reduced compared to the first technique, so that all phases of code testing are tested simultaneously, as shown in **Figure II.4** Despite this more complicated than the first strategy. However, in this technique it is possible to obtain a very long PN code, because the number of detectors placed at the same time provides us with as many PN codes as possible[11].



FigureII.4 Principle of serial acquisition [4].

As we can see, the circuit complexity of parallel search is large and the total acquisition time is much smaller than that of serial search.

II.3.3 Hybrid search:

Serial search proceeds sequentially through the entire region of uncertainty to allow a decision to be made, significantly increasing acquisition time. On the other hand, parallel search uses a number of matched filters equal to the number of possible phases, and for different PN code sequences. The parallel search system checks all possible phases simultaneously, which can reduce acquisition time considerably, but the implementation will be more complex.

Hybrid technique is elaborated as a combination of the previous techniques (serial and parallel) to overcome both their inconvenient, a solution of the time acquisition delay in the serial search and the complexity of devices in the parallel search. Hybrid types are proposed as an arrangement between the speed of acquisition and the complexity of the system[9].

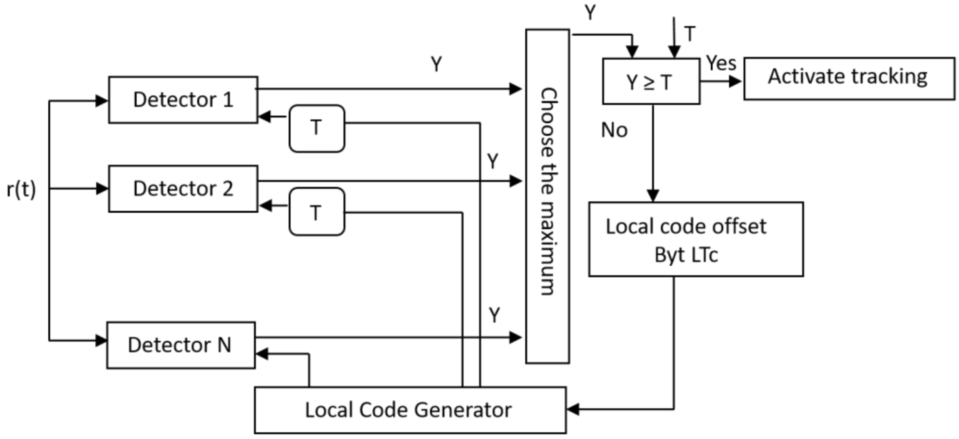


Figure II.5 Principle of hybrid acquisition [4].

II.3.4 Multi-Dwell search:

Limiting detection to a single stage is the time penalty associated with a high false alarm probability, requiring the choice of a high decision threshold to reduce the false alarm probability. Therefore, it is necessary to increase the integration time to improve the probability of detection and therefore minimize the probability of missing.

To reduce the total acquisition time is to use a second stage, as shown in **Figure II.6**.

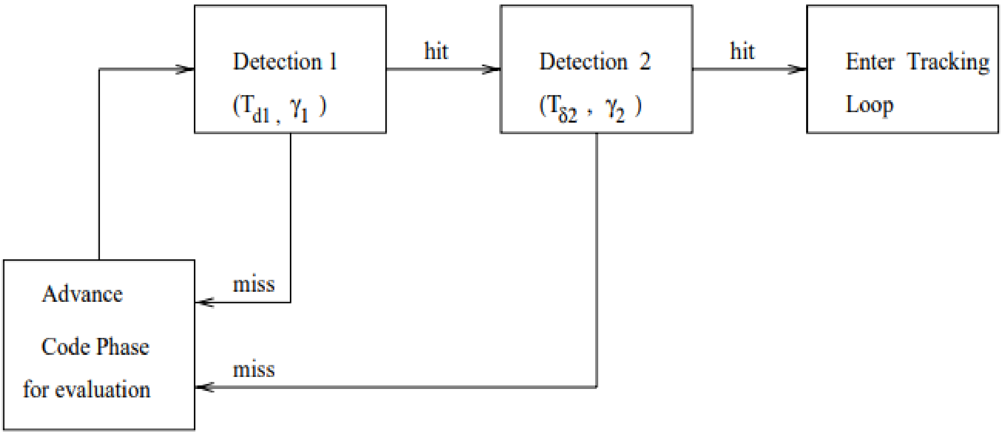


Figure II.6. Multi dwell search diagram [4].

The first detection stage is designed to have a small threshold value, and a short integration time so that the probability of no detection is low, while the probability of false alarm is large. The second stage is chosen so as to have small probabilities of false alarm and shortage. With such a configuration, the first stage can quickly reject the incorrect phases, and the second stage checks the decisions made by the first stage, to reduce the probability of false alarm. We choose suitable values for integration times and decision thresholds, the total acquisition time can be significantly reduced. This idea can be generalized easily to include more than two stages in order to minimize the overall acquisition time.

II.4 Detector techniques:

In radio frequency communication systems, the choice of the appropriate detection technique is necessary. In the case of the detection of CDMA signals, the nature of the sequences used influences the choice of the detection technique to be implemented. The threshold detector is the most commonly used for this type of system, it only takes into account the power received to make a decision, without taking into account of the information provided by the phase of the received signal, since it generally uses a non-coherent detector, which will be presented in the next section.

The detection of a bit of the data transmitted by the first user, for example, is done by setting a decision threshold sufficiently high thus, making it possible to minimize the effect of noise on the quality of detection. The level of the decision threshold must also be lower than the autocorrelation peak so that the latter can be detected. Therefore, if the level of the received power is less than the decision threshold T, it will be decided "0". On the other hand, if the power at the input of the threshold detector is greater than the decision threshold, it will be decided "1". The decision threshold is a parameter corresponding to the nature of the sequences transmitted orthogonality defects, in PN sequences used in CDMA systems, are the main causes of Multiple Access Interference (MAI). This non-orthogonality generates an overlap between the chips of the sequences of each user, which can lead to detection errors. [4]

This situation can be described in terms of statistical hypothesis testing. In general, two basic approaches detection are possible namely :

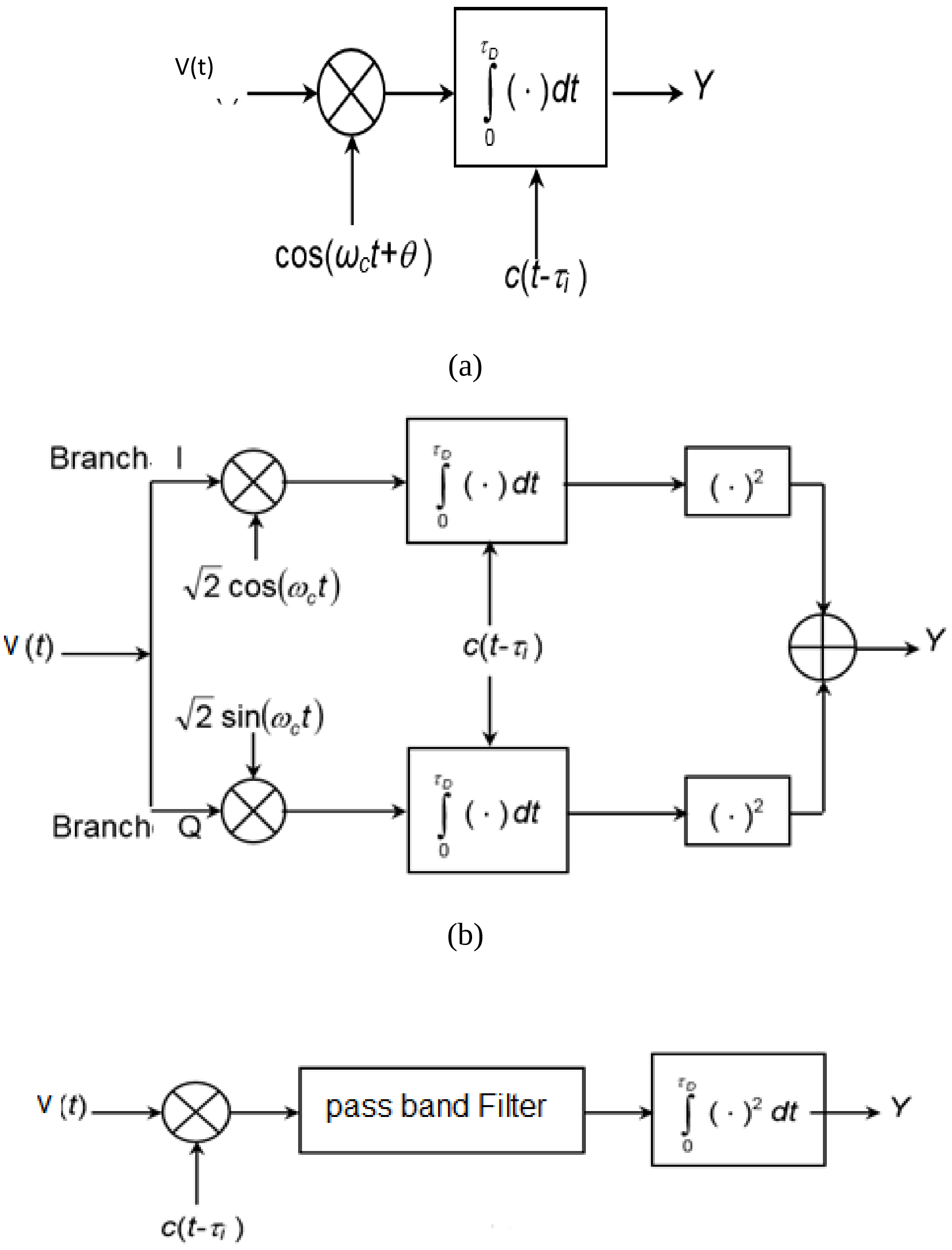
- Non-coherent (non-synchronous): H0 means that this phase τ is not aligned with that of the received PN code.
- Coherent (synchronous): H1 corresponds to the case where the phase τ to be tested is aligned with the phase of the received PN

At a given phase τ, the output of detector Y (or decision variable) Y is compared to a threshold T, to make a decision about that phase τ. When the codes (local and received) are in phase (Hypothesis 1 H), the synchronization will be detected with a probability of detection P_d. It is specified that, if the shift of the local code is less than the duration of a chip of the PN sequence; as well as in the case of the addition of thermal noise, multipath interference and signal fading, situations may be encountered where more than one synchronous position can be found in the region of uncertainty. Thus, at the synchronous position (correct phase), the detector will declare that the codes are aligned whenever the detector output exceeds the threshold value.

The integration time is the period chosen to calculate the correlation between the code received and the code generated locally. It is consulted as follows :

$$\int_0^{\tau d} V(t)c(t-\tau)dt \qquad \text{(II.2)}$$

There are three ways to detect, coherent, non-coherent and square law, as shown in **Figure II.7**



(c)

Figure II.7 Detector structures: (a) coherent detector, (b) non-coherent I-Q detector, (c) square law detector [4].

In detection devices, the detector declares whether the codes are possibly in phase by comparing the decision variable Y with a threshold, if Y exceeds the value of the threshold T, the cell H_1 will be detected with a probability of detection P_d

$$P_d = \text{prob}\ \{Y \geq T \mid H_1\} \qquad \text{(II.3)}$$

However, the probability will be considered as follows if Y does not exceed the value of T (**Figure II.1**):

$$P_m = \text{prob } \{Y<T \mid H_1\} \quad \text{(II.4)}$$

As a result of multipath channels, incorrect synchronization can motivate a probability of false alarm P_{fa} (**Figure II.1**):

$$P_{fa}=\text{prob } \{Y\geq T \mid H_0\} \quad \text{(II.5)}$$

We have the probability P_{nfa} in the case of a correct decision of non-synchronization

(**Figure II.1**):

$$P_{nfa}=\text{prob } \{Y< T \mid H_0\} \quad \text{(II.6)}$$

Usually, a false alarm generates an increase in the acquisition time. Indeed, the operation of the code pursuit will then be activated but the system will quickly realize that it is about a false acquisition. In this case, it returns to the acquisition process to resume the search after a certain time called "penalty time".

Threshold setting:

As shown in **figure II.8** the probabilities P_{fa} and P_d both depend on the T value, which means we should take caution while setting the threshold in order to gain a desired acquisition performance.

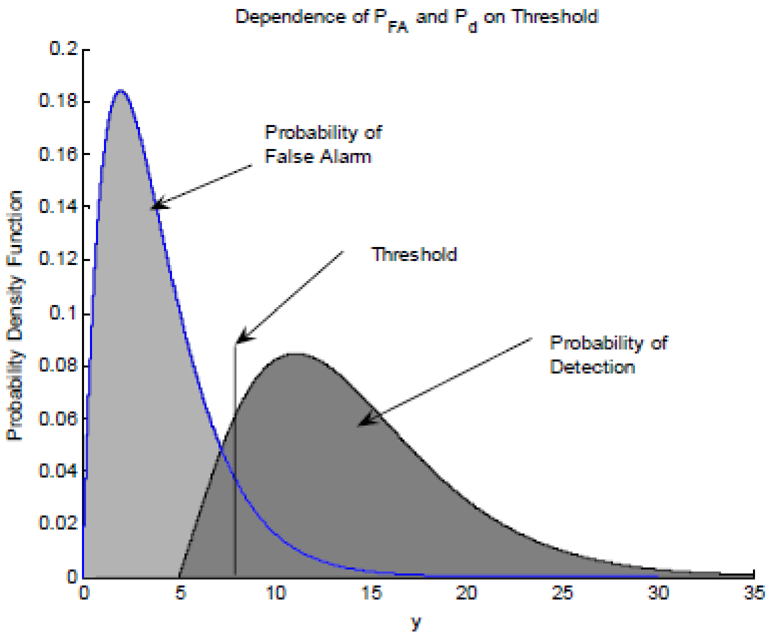


Figure II.8 Dependence of P_{fa} and P_d on the threshold value T [2].

We can Notice that the average time to accomplish depends on the level of SNR (signal/noise), P_{fa} and P_d . If the threshold is set too low P_{fa} and P_d will get bigger and at the same time, if the threshold is set too high P_{fa} and P_d will get smaller. We can result that the way affect P_{fa} and P_d the measures performances is important such as the mean time to acquisition and the hold in time.

Threshold detectors used in the context of PN sequence acquisition in CDMA systems can be classified into two main groups, depending on the method used to calculate the decision threshold, namely fixed or adaptive threshold detectors.

II.4.1 Decision criteria :

In this section, we will study the problems of decision mechanisms where the possible hypothesis are denoted by:

$$H_0 : y(t) = n(t) \quad \text{(II.7)}$$

$$H_1 : y(t) = n(t) + s(t) \quad \text{(II.8)}$$

Each hypothesis corresponds to one or more observations which are represented by random variables. And based on the observation values of these random variables, the receiver decides which hypothesis (H_0 or H_1) is true. Suppose the receiver needs to make a decision based on an observation of the received signal. The range of values that the random variable Y takes constitutes the observation space Z. This observation space is divided into two regions Z_0 and Z_1, such that if Y is in Z_0 the receiver decides in favor of H_0, while if Y is in Z_1, the receiver decides in favor of H_1, as shown in **Figure II.9**. The observation space Z is union Z_0 of Z_1 and; that is to say:

$$Z = Z_0 \cup Z_1$$

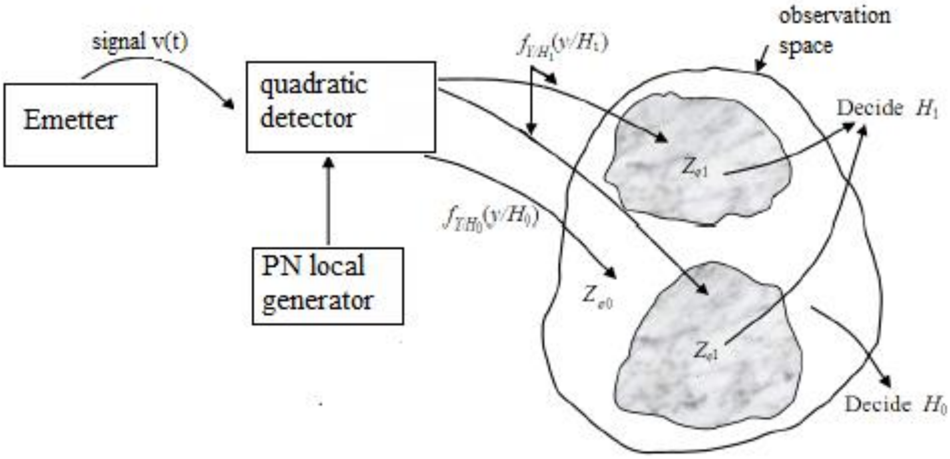


Figure II.9 Observation space for a DS-CDMA system.

Where Y represents the observations (which can be scalar, vector or samples of a signal taken in a time interval).

The PDFs of each hypothesis are $f_{Y/H1}$ (y /H_1) and $f_{Y/H0}$ (y /H_0). Each time a decision is made, four possible cases may occur:

1- Decide H_0 and H_0 vary (H_0=1 and D_0=1).
2- Decide H_0 and H_1 vary (H_1=1 and D_0=1).
3- Decide H_1 and H_0 vary (H_0=1 and D_1=1).
4- Decide H_1 and H_1 vary (H_1=1 and D_1=1).

To these four possibilities are associated four probabilities which will be used to maintain the performance of a decision criterion.

1- $P(D_0,H_0)$: No detection.

2- $P(D_1,H_0)$: 1- $P(D_0,H_0)$ = Probability of false alarm P_{fa}.

3- $P(D_0,H_1)$: Probability of no detection P_m.

4- $P(D_1,H_1)$ = 1- $P(D_0,H_1)$ = 1-P_m : Probability of detection of the target.

And we have:

$$P(D_i / H_i) = \int_{zi} f_{Y/H_j}(y/H_j)dy \qquad \text{(II.9)}$$

It is necessary to define an optimal detection strategy to delimit the decision regions Zi, which will aim to maximize the probability of detection P_d while guaranteeing a fairly low probability of false alarm P_{fa}.

The usual decision standards are the Bayes standard and the Neyman-Pearson standard.

1- **Bayes Criteria**:

This method requires prior knowledge of:

- The probabilities appearance of the two hypotheses H_1 and H_0. These probabilities are called a priori probability of the hypotheses H_1 and H_0 which are noted P_1 and P_0:

$$P_0+P_1=1 \qquad \text{(II.10)}$$

- The detection costs C which are assigned to the pairs (D_i, H_i) where D is the decision with:

$$C_{ii} < C_{ij} \qquad \forall\, i \neq j \qquad \text{(II.11)}$$

Therefore, we have to minimize the risk function R, and select a value P for which the risk is high:

$$R=E[C]=C_{00}P(D_0,H_0)+ C_{01}P(D_0,H_1)+ C_{10}P(D_1,H_0)+ C_{11}P(D_1,H_1) \qquad \text{(II.12)}$$

$$P(D_i,H_i)= P(D_i/H_j)*P(H_j)= P(D_i/H_j).P_j \qquad \text{(II.13)}$$

It’s clear that the two regions are complementary so we can write :

$$\int f_{Y/Hi}(y/H_i)dy ==1-\int f_{Y/H_j}(y/H_j)dy\ ,\ i \neq j\ ,\ i,j = 0,1 \qquad \text{(II.14)}$$

After mathematic manipulations [6] ,we have :

$$\Lambda(y) = \frac{f_{y/H1}(y/H_1)}{f_{y/H0}(y/H_0)} \qquad \text{(II.15)}$$

$$\eta = \frac{P_0(C_{10}-C_{00})}{P_1(C_{01}-C_{11})} \qquad \text{(II.16)}$$

With $\Lambda(y)$ is the likelihood ratio and η is threshold of detection.

$$\Lambda(y) \underset{H_0}{\overset{H_1}{\gtrless}} \eta \qquad \text{(II.17)}$$

The problem of this criteria is that it requires the acknowledgment of the probabilities $P(H_1)$, $P(H_0)$ and the costs C_{ij}, so in general we have to change into another criteria such as Neyman-Pearson. [9]

2- Neyman-Pearson Criteria :

Neyman-Pearson criteria is used in many filed because it does not require the acknowledgement of the priori hypotheses H_1 and H_0 also the costs C_{ij}. $P_m=(1-P_D)$. It proposes to fix the probability of false alarm P_{fa} to a fixed value α:

$$J(\beta)=P_m+ \beta(P_{fa} - \alpha) \qquad \text{(II.18)}$$

The Lagrange multiplier $\beta \geq 0$ is defined in such a way as to minimize the probability of detection P_D or minimize the probability Pm. Therefore, the decision rule is given by :

$$\Lambda(y) = \frac{f_{y/H1}(y/H_1)}{f_{y/H0}(y/H_0)} \underset{H_0}{\overset{H_1}{\gtrless}} \beta \qquad \text{(II.19)}$$

Where $f_{Y/H0}(y/H_0)$ represents the conditional probability of Y under the hypothesis H_0.

The inconvenient of this technique is that it can only be used when the processor is stationary and it's not always like this in reality. [9]

II.4.2 Fixed threshold detector:

In most detection systems, the decision-making process is done using a fixed threshold, provided the channel is stationary, when the performance is relatively efficient. The threshold is determined from the value of the desired false alarms in order to improve the probability of detection. **Figure II.10** shows a serial search acquisition system using a fixed detection threshold [4]:

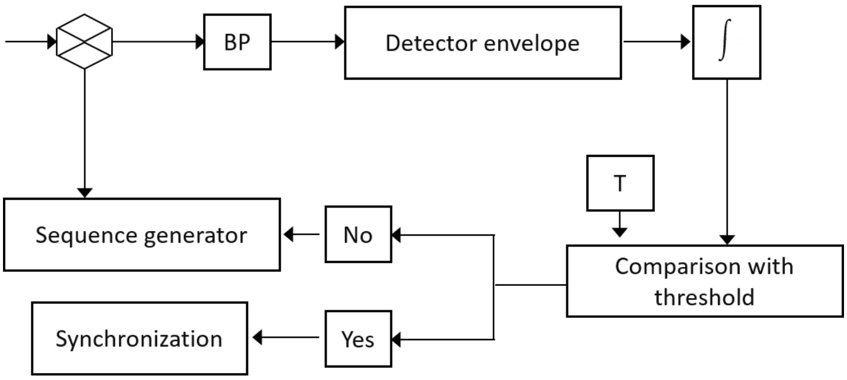


Figure II.10 Block diagram of a fixed threshold acquisition system. [4]

From the probability density function (PDF) of the signal envelope (plus noise), The false alarm probability (P_{fa}) and the detection probability (P_d) can be determined, they are defined as follows:

$$P_d = \int_T^{\infty} P(signal + noise)dz \quad \text{(II.20)}$$

And

$$P_{fa} == \int_T^{\infty} P(noise\ )dz \quad \text{(II.21)}$$

II.4.3 Inconvenient of fixed threshold detector:

The detection criteria mentioned previously are reduced to the comparison of the signal received with a fixed threshold calculated from several simulations on a well specified environment. This threshold produces either an excessive number of false alarms or a low probability of detection when the statistical characteristics of clutter and noise change. Therefore, we can imagine an optimal detection strategy meeting very strict standards concerning the probabilities of false alarm and detection. This strategy is based on the Neyman-Pearson standard. [5]

We can calculate the probability of false alarm P_{fa} and deduce the detection threshold β, by considering an AWGN channel whose pdf is given by:

$$f_{y/H0}(y/H_0) = \frac{1}{2\sigma^2_N} e^{-\frac{y}{2\sigma^2_N}} \quad \text{(II.22)}$$

Or

$$P_{fa} == \int_{\beta}^{+\infty} f_{y/H0}(y/H_0)dy = e^{-\frac{\beta}{2\sigma^2_N}} \quad \text{(II.23)}$$

After the correlation and fixing P_{fa} at 10^{-4} and knowing the variance of noise σ_N^2 , the threshold becomes :

$$\beta=-2\sigma_N^2 \ln(P_{fa})=-B\ln(P_{fa})=9.21B \tag{II.24}$$

Where B= $2\sigma_N^2 = N_0$ NT=2(N_0/2)(NT).

By normalizing the power of the noise to unity, we get β =9.2. The probability of false alarm nominal could be given by the expression:

$$P_{FAnom}=10^{-4}=exp\left(-\frac{9.21}{B_{nom}}\right) \tag{II.25}$$

Where B_{nom} =1.

$$P_{fa}=e^{\frac{-\beta}{B}} = (e^{-\beta})^{\frac{1}{B}}=(P_{FAnom})^{\frac{1}{B}} \tag{II.26}$$

In this equation, B is affected by the variation of its Power spectral density which is equal to (N_0/2), or by the variation of partial correlation length of non-coherent detector.

We notice that the detection threshold and the noise power intervene at the level of the exponent of the false alarm probability given by equation (II.26). Any error in estimating any of these two parameters implies a huge deviation from its nominal value.

As we mentioned previously the fixed threshold provides either a huge number of false alarms or a low probability of detection as illustrate in **Figure II.11:**

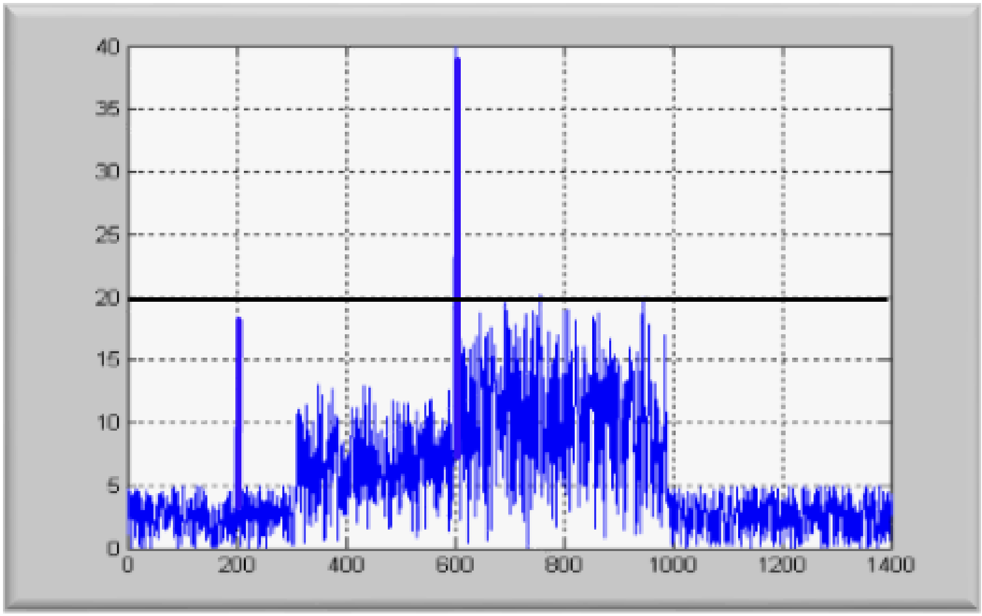


Figure II.11 Detection using a fixed threshold.

From **figure II.11**, we can notice that the fixed threshold limited the probability of detection number. [9]

II.4.4 Adaptive threshold detector:

Like was mentioned previously, the common acquisition methods using a fixed threshold value poses problems of varying detection and false alarm probabilities when the environment changes. To choose a threshold value, a conventional system performs several tests with different threshold values by simulation in a specific environment. After several tests, the system chooses an optimal threshold value, so these systems are unqualified to give a good quality of service for users.

To solve this issue we use a well-known Algorithm called CFAR (Constant False Alarm Rate) which is based on changing adaptively the threshold's value, achieving a constant false alarm rate. Therefore, the acquisition system will be able to adapt the different mobile communication environments, it will be more detailed in the next chapter. [12]

II.5 Conclusion:

In this chapter, we have presented the two phases of PN code synchronization in DS-CDMA systems initial acquisition phase and Tracking phase. We approached the theory of signal detection and search strategies.

We also have mentioned in details that the fixed threshold detector and that it might causes problems such as errors, perturbations and false alarms. To avoid these problems we change into an adaptive acquisition, which uses algorithms vary depending on environments changes. This technique will be discussed in details in the next chapter.

CHAPTER III

Adaptive acquisition using CA-CFAR algorithms

Summary :

III.1 INTRODUCTION.
III2 ADAPTIVE ACQUISITION.
III.3 CFAR DETECTOR.
III.4 CA-CFAR (CELL AVERAGING CFAR).
III.5 CFAR LOSS.
III.6 SIMULATION AND DISCUSSION.
III.5 CONCLUSION.

III.1 Introduction:

In all of the works cited so far, the decision-making process is based on the use of a fixed threshold. Under the condition of a stationary channel, the threshold can be set and these systems can provide relatively efficient performance. But as soon as the channel becomes non-stationary, the fixed threshold detector can cause a considerable increase in the probability of false alarm (P_{fa}). These systems are therefore unable to offer good performance due to their lack of ability to adapt to the various changes that may appear in the propagation environment.

To overcome this problem, acquisition systems based on adaptive threshold detectors have been the subject of much research. In these studies, the system uses the results of the correlator to estimate the level of background noise and thus provides a threshold that adapts to variations in the environment. On the other hand, transmitting the signal in an echo-rich propagation environment, the overall signal received represents the contribution of an unknown number of replicas of the initially transmitted signal. Each of the replicas is characterized by a power attenuation and a specific delay time. To by-pass the effect caused by the presence of multipath, some researchers propose a processor based on statistics order (OSAP)where the K^{th} sample is used to estimate the noise power, in the other hand some researchers proposed an adaptive acquisition processor (AAP).

The basic idea of AAP (k) is to align the samples in ascending order. Then, the largest samples k are censored and the sum of the remainder is used to estimate the noise level. Another adaptive acquisition system, based on an excision threshold, has been proposed for an additive noise channel. However, in these acquisition systems the k censor point or excision threshold is preset for all environments, while in practical applications the number of replicas is not only unknown but may vary over time. Therefore, if the number of cells to be censored is incorrectly chosen, the system may exhibit a significant degradation in detection and consequently a considerable increase in the average acquisition time.

III.2 Adaptive Acquisition:

Generally, PN code acquisition does not give satisfactory performance while using a fixed threshold because it might cause many false alarms or reduce the probability of detection. For this, an adaptive threshold acquisition technique was used which is based on algorithms well-known by CFAR (Constant False Alarm Rate).

The basic idea of CFAR algorithms is to calculate the threshold from the pdf of the signal of the output of the non-coherent detector with the hypothesis H_0. It allows us to calculate the multiplicative constant T by setting the probability of false alarm P_{FA} to a minimum desired value. Thus, the threshold will be the arithmetic product of the value of T (calculated from the previously fixed probability of false alarm) and the power of the noise X estimated in real time, depending on variations in environmental conditions[12].

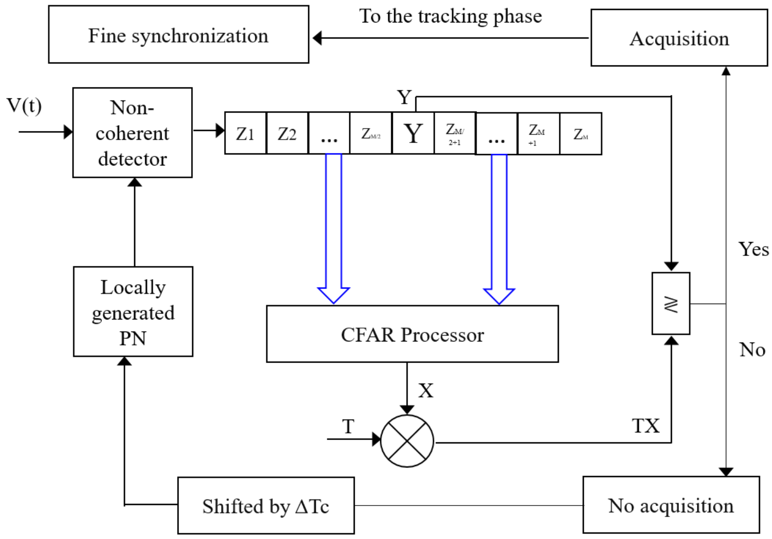


Figure III.1 Block diagram of an adaptive threshold acquisition system [9].

Figure III.1 shows the principle of the CFAR detection technique. The samples leaving the detector are sent in series to a shift register of length M + 1. The M cells Zi, i = 1,…, M, called reference cells, represent the outputs of the non-coherent detector which correspond to the different possible shifts (phases) of the PN sequence. The X statistic is calculated by processing the M reference cells. Cell Y, called the Cell Under Test (CUT), represents the detector output that corresponds to the phase of the PN sequence that we want to test.

If the value of Y exceeds the value of the adaptive threshold, then we can say that the locally generated PN sequence is synchronized with the received PN sequence. Therefore, the tracking loop is activated in order to achieve fine synchronization between the two PN sequences to decipher the information received.

If the value of Y is less than the value of the adaptive threshold X_T, the phase of the received PN code is therefore not synchronized with that of the locally generated code. Therefore, the local PN code is delayed by a duration Δ_{TC} in order to test other cells. In our work, the value of Δ is fixed at 1.

III.3 CFAR Detector:

In order to analyze the detection performance of the CFAR Processor, it is assumed that the output of the quadratic detector for any range of cells is an exponential distribution. With a probability density function (PDF):

$$f(Z_i) = \frac{1}{\lambda} \exp\left(-\frac{Zi}{\lambda}\right) \quad ; \quad x \geq 0 \tag{III.1}$$

Where λ equal to μ the total power of noise ("clutter" plus thermal noise) in the absence of target (hypothesis H_0). And, in the presence of the target (hypothesis H_1) λ equal to μ (1 + s), where S is the average of the total signal to noise (SNR) of a target.

So we can write:

$$\lambda = \begin{cases} \mu & Hypothesis\ 0 \\ \mu(1+S) & Hypothesis\ 1 \end{cases} \qquad \text{(III.2)}$$

where $\mu = 2\sigma^2$

From equation (III.2) and by putting $\mu = 1$, the expression of the conditional probability density of the cell under test becomes:

$$f_{Y|Hi}\,(y|H_i) = \begin{cases} \exp(-Y) & Hypothesis\ 0 \\ \frac{1}{(1+S)}\exp\left(\frac{-Y}{(1+S)}\right) & Hypothesis\ 1 \end{cases} \qquad \text{(III.3)}$$

The optimal detector sets a threshold for determining the presence of target under the assumption that the total noise power is known a priori. In this case, the probability of detection is given by :

$$P_D = P_r\left[\ y > XT \mid H_1\right]$$
$$= \int_0^{\infty} Px(x)dx \int_{XT}^{\infty} P_{y|H1}\,(y|H1)\,dy \qquad \text{(III.4)}$$

And the probability of a false alarm is given by:

$$P_{FA} = \left[Y > XT \mid H_0\right]$$
$$= \int_0^{\infty} Px(x)dx \int_{XT}^{\infty} P_{y|H0}\,(y|H0)\,dy \qquad \text{(III.5)}$$

Where $P_x(x)$ represents the probability density function of the variable X;

$P_{y|H0}$ (y|H0) dy and $P_{y|H1}$ (y|H1) dy are the conditional probability density functions of the random variable Y under the hypotheses H_0 and H_1.

In CFAR detection, we divide the number of cells M into two windows [6] which are often designated by the letter U for the right window and V for the left and this notation is used in particular to designate their respective sums:

U is the average of the leading reference window:

$$U = \frac{2}{M}\sum_{i=1}^{M/2} Zi \qquad \text{(III.6)}$$

And V is the average of the lagging reference window:

$$V = \frac{2}{M}\sum_{i=\frac{M}{2}+1}^{M} Zi \qquad \text{(III.7)}$$

III.3.1 CFAR Types:

As we mentioned previously, CFAR algorithms vary according to the way in which the statistical test is obtained, we can classify cfar detector in to three main groups[9]:

- CFAR Conventional Detector.
- CFAR detectors with fixed censor points.
- CFAR detectors with automatic censor.

Among these three groups we can cite some examples:

a- GO-CFAR (Greatest Of CFAR) and SO-CFAR :

We use GO-CFAR detector to control the unwanted increases in the probability of a false alarm ,by comparing the arithmetic sums of the two windows U and V and chooses the greatest value, in another word, set the noise level in the CUT to be Maximum of U and V , X=max (U,V).

We can say The same thing for SO-CFAR, we just chose the smaller value between U and V, X=min(U,V), as shown in **figure III.2**.

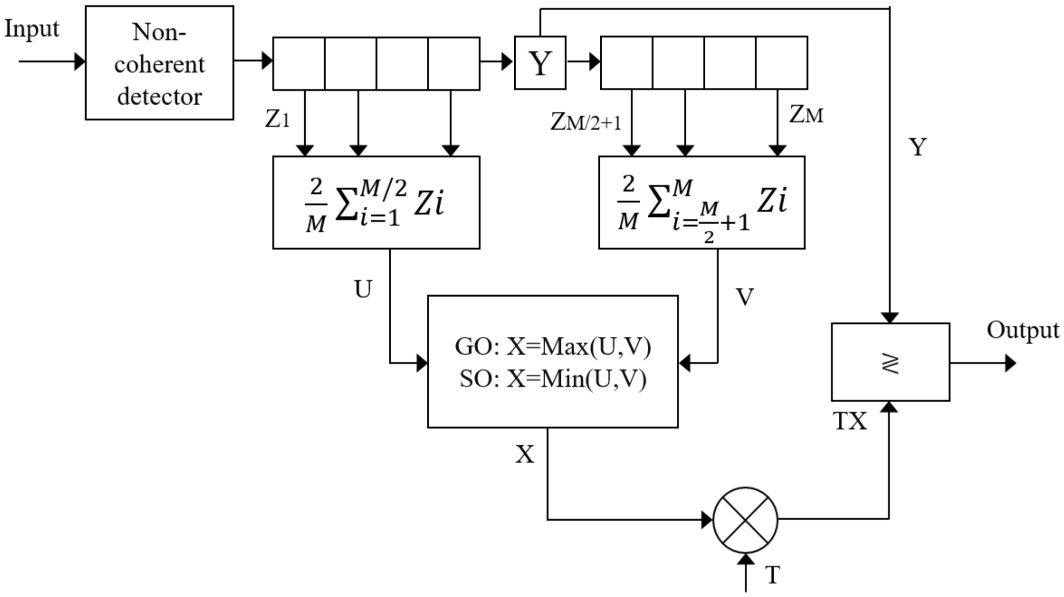


Figure III.2 The bloc diagram GO-CFAR and SO-CFAR. [9]

b- OS-CFAR (Order Static CFAR):

In this detector, the samples of the reference window are classified in ascending order as following:

$$Z_1 < Z_2 < Z_3 < \ldots < Z_{(k)} < \ldots < Z_{M-1} < Z_M \qquad \text{(III.8)}$$

The output X of OS-CFAR processor is given by X= $Z_{(k)}$ .The signal from CUT is compared to the XT adaptive threshold.

There are other CFAR detectors left such as CA-CFAR and ATM CFAR…etc.

III.3.2 Efficient CFAR requirements :

- Low CFAR-loss.
- Precise fitting of the CFAR threshold to the clutter scenario.
- Proximately spaced targets must not mask each other.
- High performance with respect to required processing power and production costs.

III.3.3 Radar environment:

There exists two environments used to evaluate the efficiency of various CFAR algorithms: Homogeneous and Non-Homogeneous environment [10].

- Homogeneous environment: it assumes that the noise echoes are distributed in homogeneous way in which the samples are independent and identically distributed. It may appear when the clutter's echo comes from a constant environment (ocean, forest, mountain…etc).

- Non-Homogeneous environment: when the reference window scans the environment in a given direction, different non-homogeneous situations can affect the configuration of reference cells. These situations are caused by the presence of interfering targets and clutter edge.

III.4 CA-CFAR (Cell Averaging CFAR):

Another types of CFAR, a very well-known processor in the field of radar detection we did not mention in the previous section called CA-CFAR. In this thesis, we will study this type of CFAR detection in a homogeneous environment.

CA-CFAR detector consists in comparing the sample of the CUT with an adaptive threshold XT equal to the sum of the contents of the reference window multiplied by a constant T [3] which ensures a desired probability of false alarm in a homogeneous environment (see **Figure III.3)**

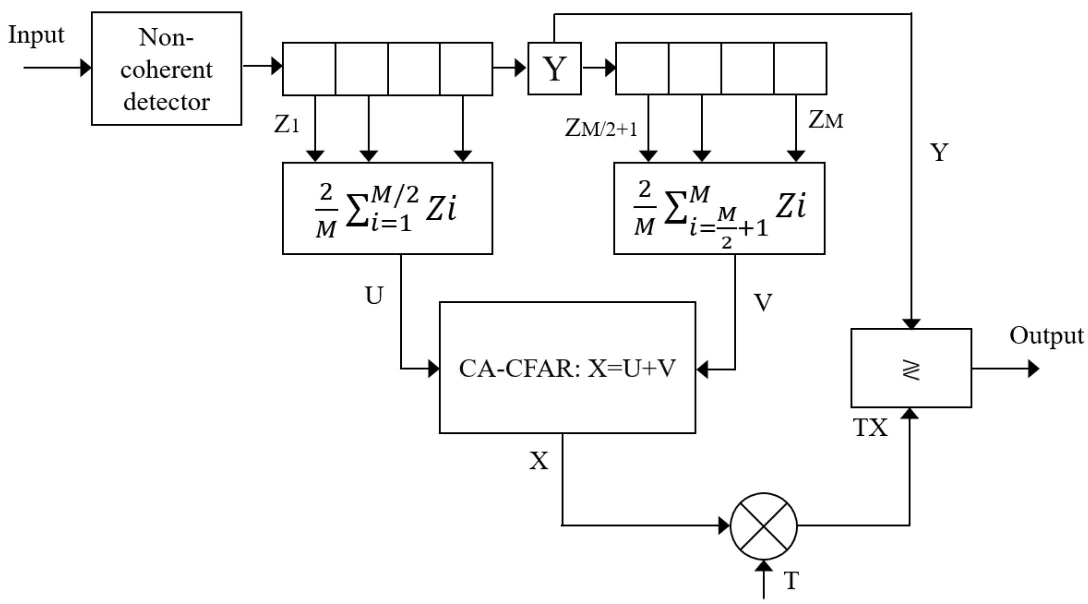


Figure III.3 The bloc diagram CA-CFAR [9].

The total noise power X is estimated by the sum of cells in the reference window:

$$X=U+V=\sum_{i=1}^{M} Zi \quad \text{(III.9)}$$

Where Z i is the range of cells surrounding the cell under test.

The probability density functions of the random variable X is

$$P_x(x)=G(M,1) \quad \text{(III.10)}$$

Where G(M,1) is the distribution Gamma with the parameter M and 1, so :

$$P_x(x)=\frac{1}{\Gamma(M)}\, x^{M-1} \exp(-x) \quad \text{(III.11)}$$

To deduce the expression of the probability of detection of CA-CFAR, we suppose that a primary target is present in the cell under test (hypothesis H1), in this case, we replace the equations (III.3) and (III.11) in (III.4) and obtain :

$$P_D=\left[1+\frac{T}{1+S}\right]^{-M} \quad \text{(III.12)}$$

And by setting S=0, the probability of false alarm becomes :

$$P_{fa}=[1+T]^{-M} \quad \text{(III.13)}$$

From the equation (III.13) we can give the expression for the scale factor T :

$$T=(P_{fa})^{1/M} -1 \quad \text{(III.14)}$$

It is clear from equations (III.12) and (III.13) that the probabilities of detection and false alarm P_D and P_{FA} are independent of μ. When the number of reference cells becomes large ($M\rightarrow \infty$),

The CFAR detector approaches optimal detector.

$$P_D= \lim_{M\to\infty}\left(1+\frac{T}{1+S}\right)^{M}$$

$$=\exp\left(\frac{-T}{1+S}\right. \quad \text{(III.15)}$$

$$P_{fa}= \lim_{M\to\infty}(1+T)^{M}$$

$$=\exp(-T) \quad \text{(III.16)}$$

From equation (III.16) we can cite the relation between probability of false alarm and the probability of detection (Neyman-Pearson formula):

$$P_D = P_{fa}^{(1/(1+S)} \qquad (III.17)$$

From the equation (III.14) we can give the table III.1 which represents the relation between the scale T , P_{fa} and M :

	T			
Number of cells M	P_{fa}=10^-4	P_{fa}=10^-6	P_{fa}=10^-8	P_{fa}=10^-10
8	2.182	4.623	9.00	9
16	0.778	1.371	2.162	3.21
24	0.468	0.778	1.154	1.61
32	0.344	0.540	0.778	1.05

Table III.1 relation between M,T and Pfa.

III.4.1 Advantages and disadvantages of CA-CFAR:

➢ Advantages:

- Require little processing power.
- Having low CFAR loss.
- Perfect performance in homogenous environment.

➢ Disadvantages:

- Closely spaced targets can mask each other .
- Ca far can not immediately follow a brief rise or fall in clutter level.
- Inffective thresholding .
- Low performance in non-homogenous environment.

III.5 CFAR Loss:

CFAR loss is a method used to measure the relative performance of CFAR processors[9].

The quality of the CFAR detector is defined by the CFAR loss: it is the difference in dB of the signal to noise ratio (SNR) of a CFAR detector and that of a fixed threshold detector necessary to provide the same probability of detection. In this case, the fixed threshold detector is said to be the ideal CFAR.

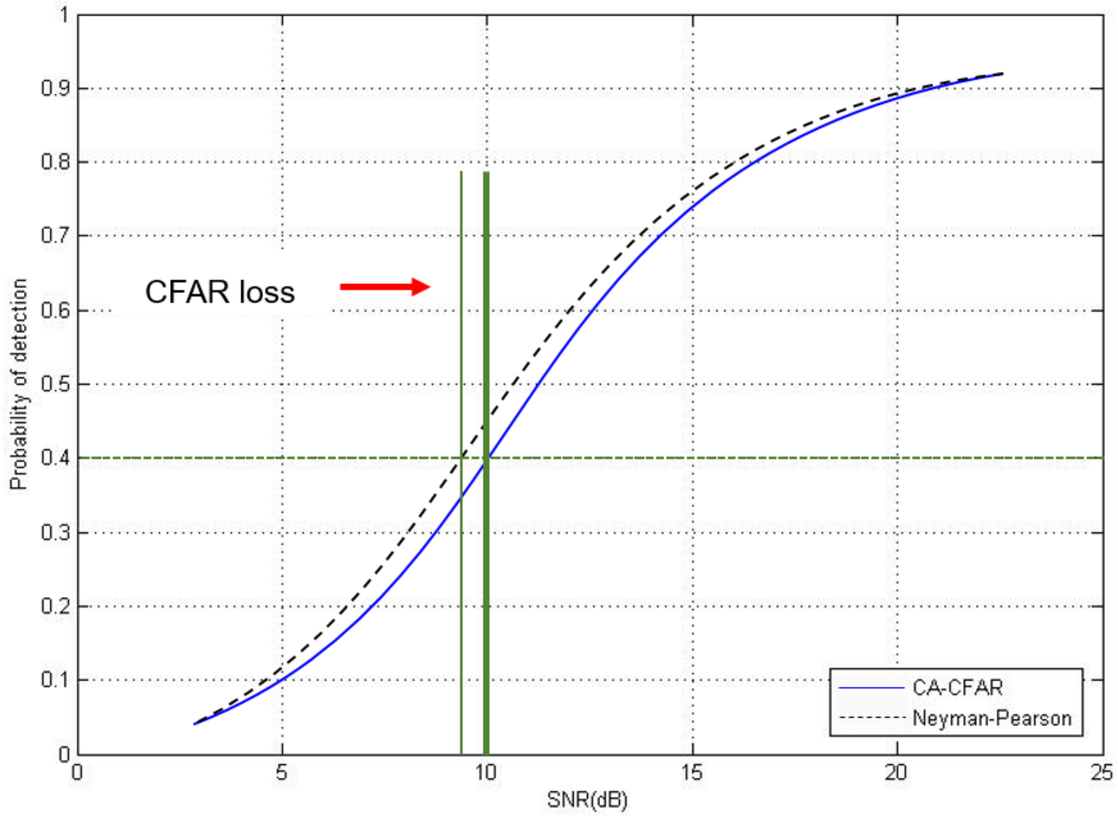


Figure III.4 Probability of detection with a CFAR-loss curve.

Figure III.4 shows the probability of detection graph as a function of SNR. The probability of detection increases with increasing SNR. The Neyman-Pearson detector represents the best theoretical detection if the knowledge of the main noise is known a priori.

III.5 Monte-Carlo method:

Monte-Carlo method is a purely statistical method. It comprises in estimating the probability of detection P_d by the ratio between the number of samples exceeding a pre-established threshold “mb exceeding” and the total number “M” of samples generated in a simulation[6].

The number of overruns is obtained by comparing the sample delivered by the decision block with the sample sent by the source in a simulation.

$$P_D=\frac{mb\_exceeding}{M} \quad \text{(III.18)}$$

After the comparison between the sample delivered by the decision bloc and the sample sent by the source in a simulation, we obtain mb_exceeding. The P_D estimator is a random variable with average P_D and variance P_D * (1- P_D) / M if the samples are assumed to be independent. The estimate is consistent, because the quadratic error tends to zero as M tends to infinity [9].

In radar application, this method is adopted when we face situations where analytical formulas cannot be obtained or when their forms do not easily adapt to numerical computation. The idea is based on the generation of a sufficient number of samples corresponding to the Gaussian noise of known parameters, then the adaptive threshold is calculated from these samples after having fixed the probability of false alarm.

The signal and the noise at the receiver level can be given by:

$$S+N=N\,(1+S/N)=N\,(1+SNR) \quad \text{(III.19)}$$

Therefore, one can simulate the samples of the received signal for different values of SNR, the detection probability is calculated by the ratio of the number of samples which exceeds the threshold on the total number of samples simulated for each value of SNR.

III.6 Simulation and Discussion:

III.6.1 Posing Problem:

In this section, we generated with MATLAB a random signal of 70 samples that will be used to simulate the CA-CFAR detection method. The purpose of this simulation is to analyze the characteristics of this detector by plotting its adaptive threshold in different environments and studying the probability of detection of CA-CFAR as a function of the signal to noise ratio for different probabilities of false alarm and different values of the number of reference cells in homogenous and non-homogeneous environments.

We consider a series of Monte Carlo simulations for the calculation of probability of false alarm and probability of detection for different environments. The assumptions we have considered are as follows:

- A QED quadratic envelope detector.
- An exponential distribution clutter.
- A region of uncertainty =1023.
- A time chip $T_c=10^{-6}$.
- A penalty time K=1000.
- A number of cells of reference M=8,16 and 24.

Therefore, we treat the following cases:

- Homogeneous clutter.
- Non-homogeneous clutter (one interfering target).

III.6.2 Case of a Homogeneous clutter:

To understand the relation between the probability of detection of CA-CFAR and Neyman-Pearson optimal probability, we execute the appropriate MATLAB program and obtain the following figure:

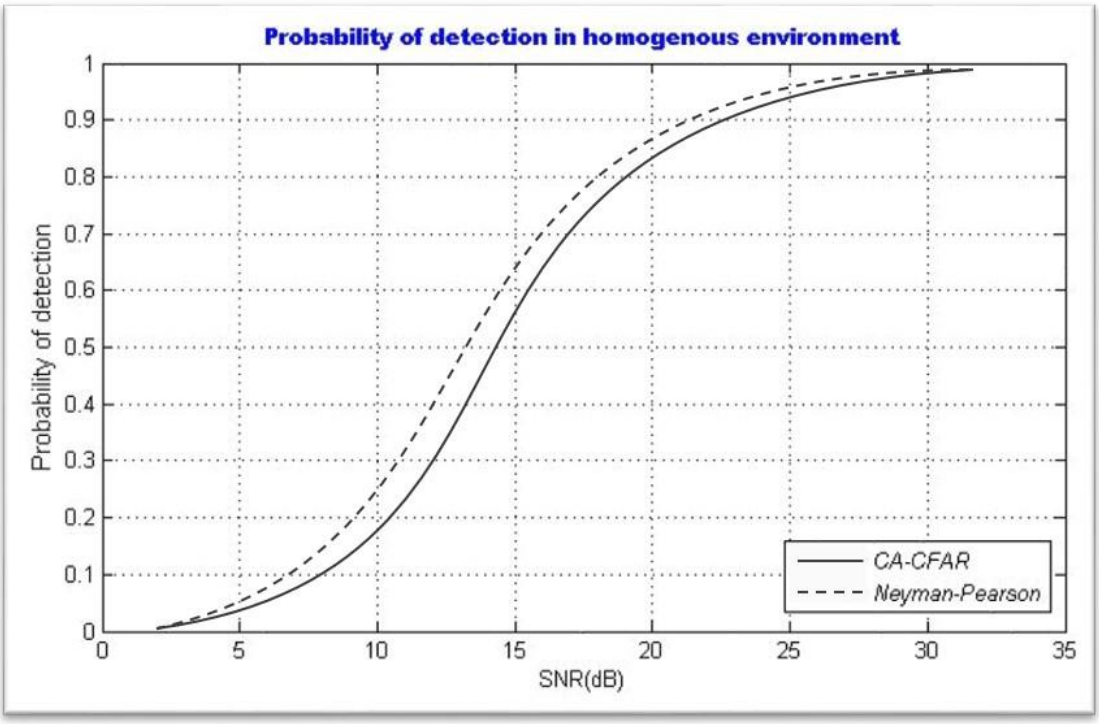


Figure III.5 Curve of P_D CA-CFAR and Neyman-Pearson in a homogeneous environment.

FigureIII.5 represents the probability of detection of CA-CFAR and Neyman-Pearson optimal probability as a function of SNR with number of cells=32. We notice that P_D CA-CFAR variation is very similar with Neyman P_D. Therefore, we can conclude that in this environment there is a directly proportional relationship between them.

In the following section, we will present the variation of the detection probability for the CA-CFAR detector as a function of the SNR. The results are shown in the following figures:

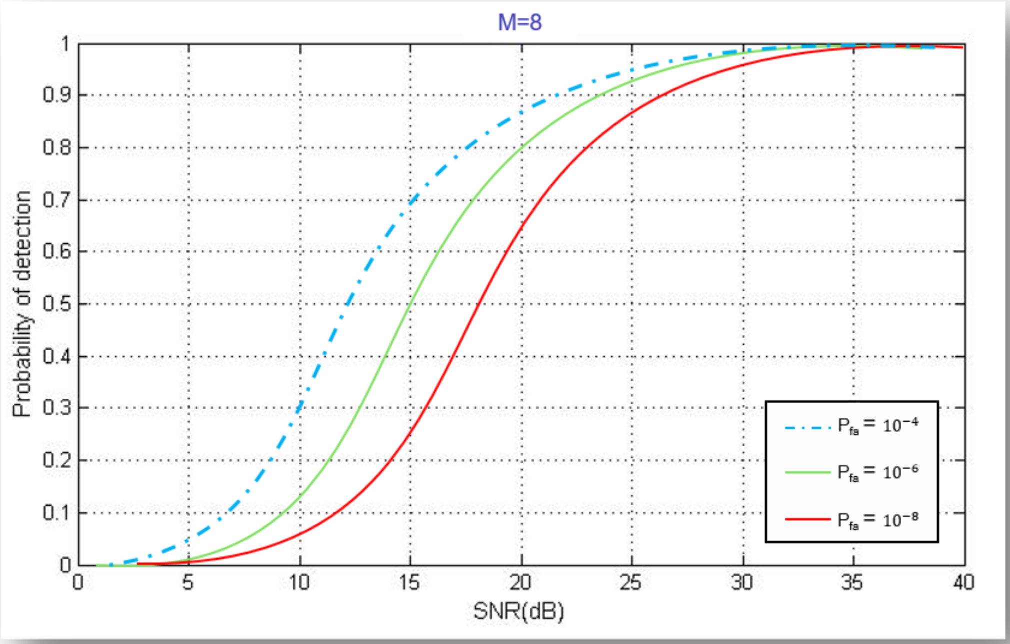


Figure III.6 Probability of detection of CA-CFAR as a function of the signal-to-noise ratio with Pfa as parameter M = 8.

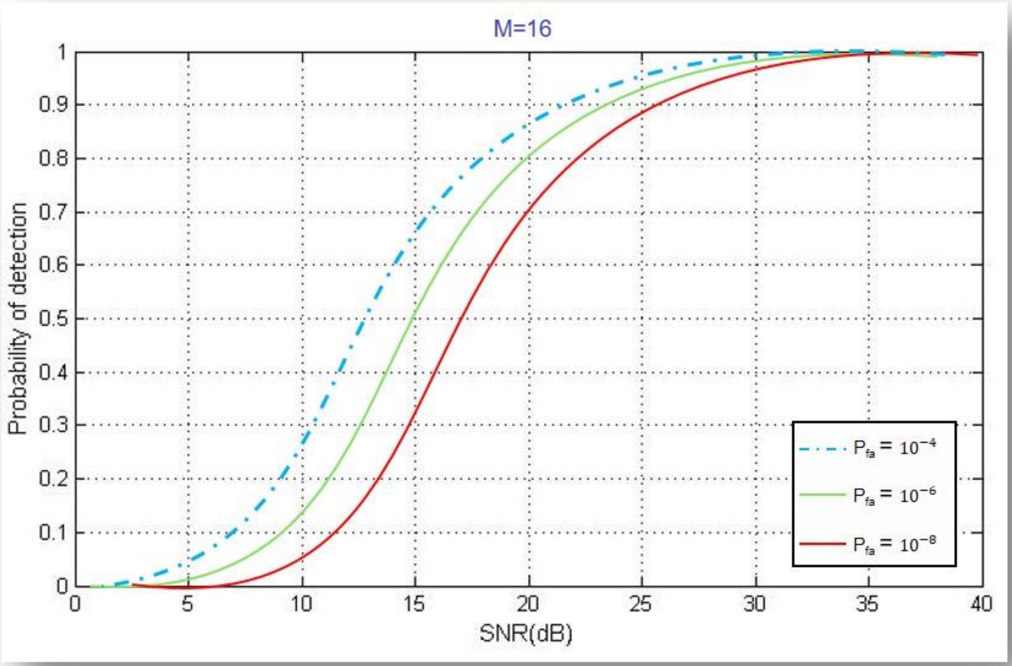


Figure III.7 Probability of detection of CA-CFAR as a function of the signal-to-noise ratio with Pfa as parameter M = 16.

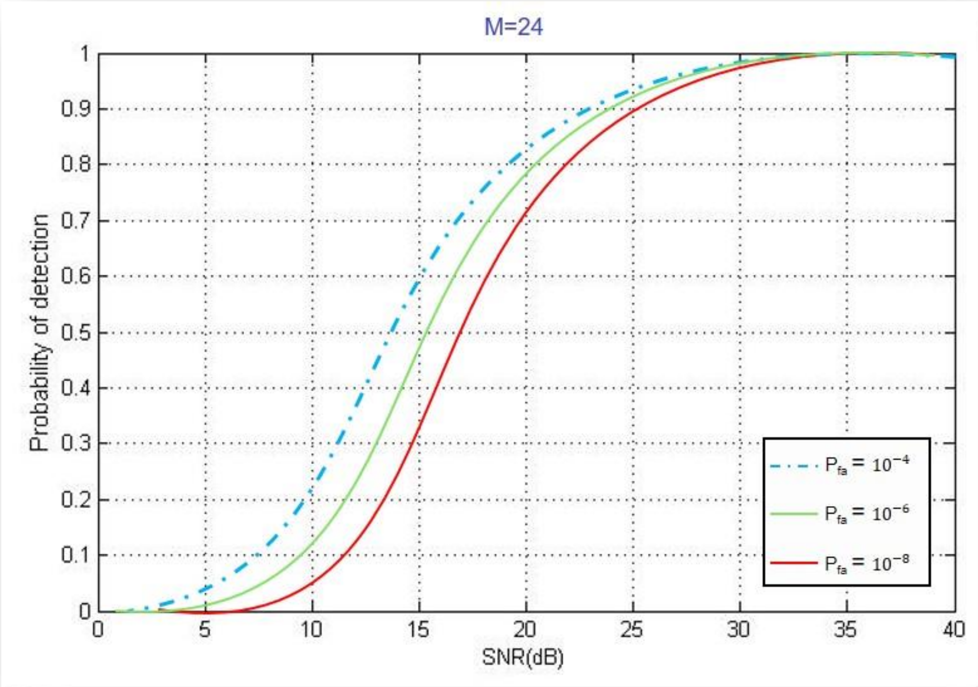


Figure III.8 Probability of detection of CA-CFAR as a function of the signal-to-noise ratio with Pfa as parameter M = 24.

These figures illustrate the probabilities of detection as a function of SNR for a probability of false alarm $P_{fa}=10^{-4}$, $P_{fa}=10^{-6}$ and $P_{fa}=10^{-8}$.

We have three cases have been examined using Monte Carlo method; we fixed the number M of reference cells and took the probability of false alarm as a parameter and vice versa.

We can notice from **Figure III.6, Figure III.7** and **Figure III.8** that the signal to noise ration increases also does the probability of detection. And this was a predictable results because the less noise, the easier detection of possible targets.

We can also note that the case of M= 24 is better than the case of M= 16 and better of case M=8 for the same value of SNR because par example in the case of M=24 the P_D is bigger than P_D in the case of M=16 and for sure bigger than P_D in the case of M=8.

For SNR = 5 the Pd in the case of M= 24 is equal to 0.1 while the Pd in the case of M = 16 is equal to 0.05 and in the case of M=8 is equal to 0.02. We also remark that the probability of detection goes in the same direction as the probability of false alarm

We can explain this result by the more we try to detect more targets, the more probably we are to make errors in mistaking noise peaks for targets.

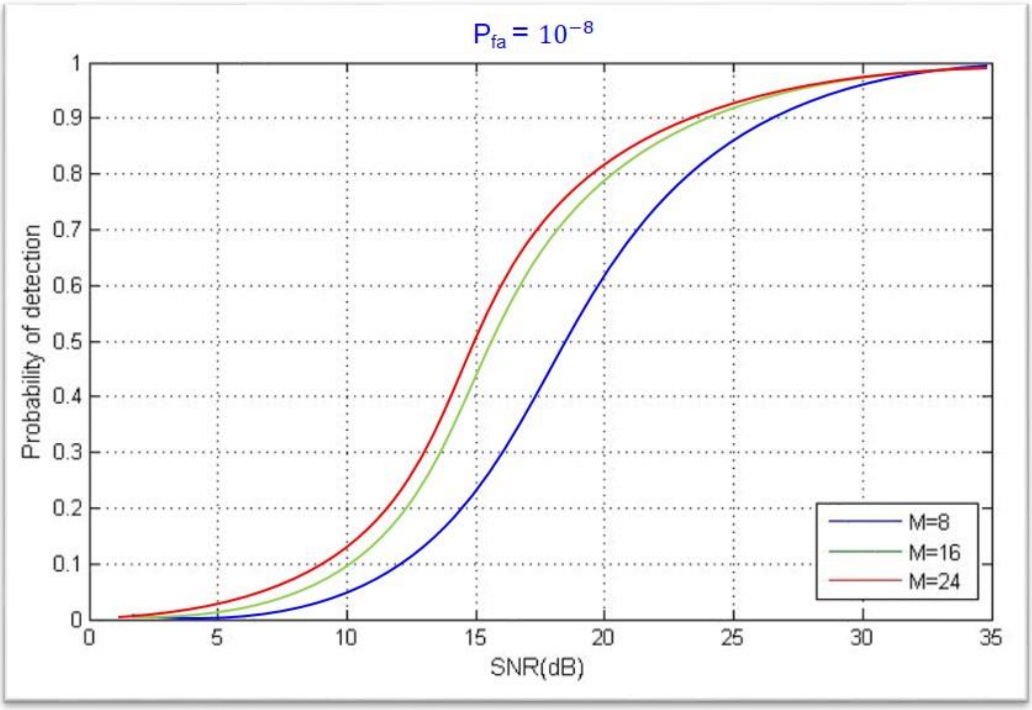


Figure III.9 Probability of detection of CA-CFAR as a function of the signal-to-noise ratio with M as parameter.

In **figureIII.9** we presented the variation of the detection probability for the CA-CFAR detector as a function of the SNR by fixing the probability (10^{-8}) of false alarm and took the number M of reference cells as a parameter.

We can notice that that for the same signal to noise ratio value, the probability of detection improves when the number of reference cells increases. Theoretically, the greater the number of reference cells, the better estimation of the surrounding noise, the more the CA-CFAR approaches the optimal Neyman-Pearson probability. However, this number cannot be taken too large because we must estimate the direct entourage of the target. We should mention again that these results are based on the hypothesis that the clutter is homogeneous.

- **Conclusion 1:**

We conclude that the main factor influencing the probability of detection P_D is the number of effective cells in another word the more number of cells increases, the more probability of detection increases for a small SNR value.

CA-CFAR detector shows very satisfactory results in a homogeneous environment.

III.6.3 Case of Non Homogeneous clutter:

In reality, all received signals consist of a signal reflected by the target, noise and clutter. this situation goes beyond the homogeneous case from which it is necessary to carry out a study on detection in a non-homogeneous environment.

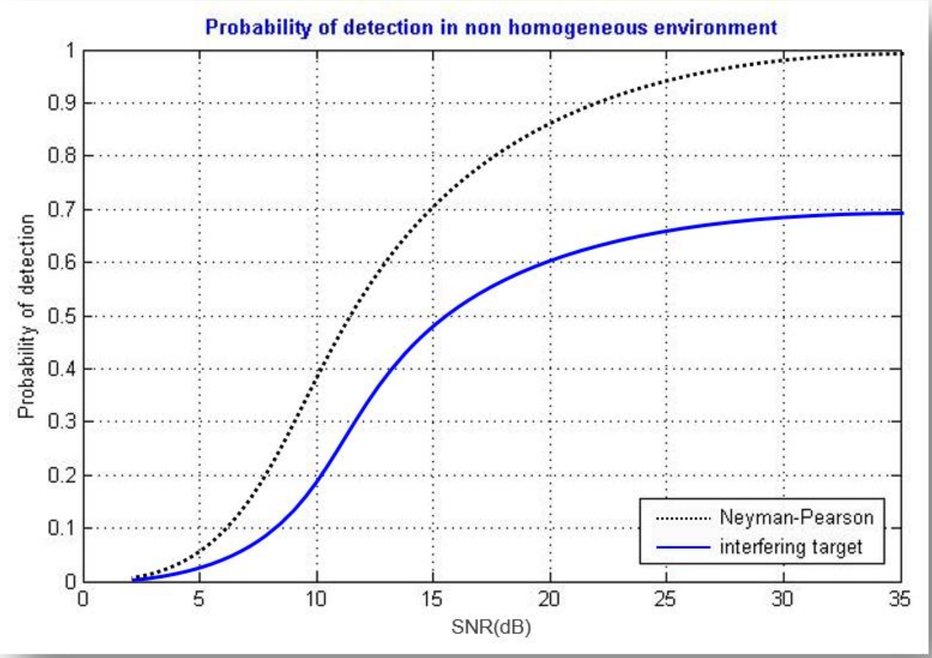


Figure III.10 Probability of detection of CA-CFAR as a function of the signal-to-noise ratio in a non-homogenous environment.

As we can notice in **figureIII.10,** the probability of detection of CA-CFAR is lower than the probability of Neyman-Pearson in the case of one interfering target.

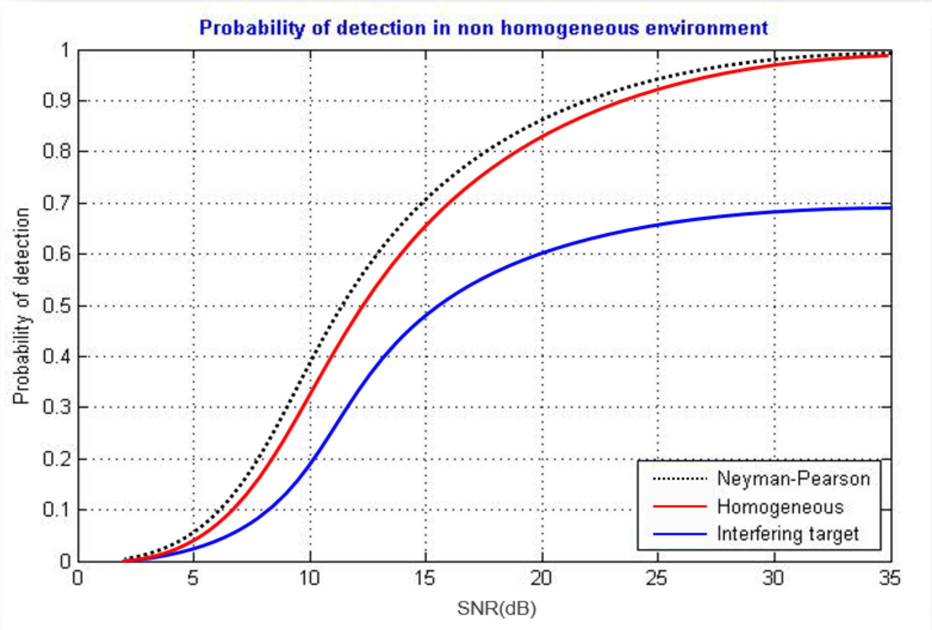


Figure III.11 Comparison between Neyman-Pearson and homogeneous clutter in non-homogeneous (1 interfering target).

As illustrated in **figureIII.11**, the probability of detection in non-homogeneous environment (1 interfering target) is lower than the one in homogeneous environment.

We can explain this

- **Conclusion 2:**

We conclude that CA-CFAR detector shows unsatisfactory results in a non homogeneous environment in presence of one interfering target.

III.7 Conclusion:

In this chapter, we have presented adaptive acquisition, which is based on CFAR (Constant False Alarm Rate) Algorithms. We also mentioned different types of detectors and their principles.

Finally, we discussed the different results of CA-CFAR performances in both homogeneous and non-homogeneous environment.

General conclusion

In our work, we have addressed the problem of adaptive acquisition of pseudorandom sequences in DS / CDMA communication systems. These systems are based on the technique of spread spectrum modulation, where several users could transmit its data simultaneously and over the entire frequency band. Using pseudo-random codes specific to each of them, each user's own signal looks like random noise to other users on the same channel. However, communication requires a synchronization process, which is carried out in two stages: acquisition and tracking.

Because of the instable conditions of the propagation environment, good acquisition cannot be achieved using a fixed threshold detector. These facts dictate the use of a receiver with a constant false alarm rate CFAR , which is based on an adaptive detection threshold, which we have explained in chapter II.

The main objective of this work was to improve the performance in terms of detection and acquisition time of PN code synchronization, which is a very crucial step in the systems considered.

To achieve this goal, we have studied and simulated CA-CFAR detector in two environments homogenous and non-homogenous. MATLAB was used for building the proposed system and carrying out simulations. This work was organized as follow:

Chapter one: State of the art.

Chapter two: PN code synchronization.

Chapter three: Adaptive acquisition using CA-CFAR algorithms.

Future work:

In this work we used a serial search strategy, So it will be interesting to use another search strategy.

In order to minimize the false detection and the missing detection caused by the fixed threshold, we have studied the adaptive threshold by simulating CA-CFAR detector which, showed a satisficing results in homogenous environment but unfortunately we can not say it's the same thing in non-homogeneous environment, therefore it is necessary to solve this problem and study the other types of CFAR detectors.

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