Module
7

Spread Spectrum and Multiple Access Technique

Lesson 39

Code Acquisition

After reading this lesson, you will learn about

- ***Basics of Code Acquisition Schemes;***
- ***Classification of Code Acquisition Schemes;***

Code synchronization is the process of achieving and maintaining proper alignment between the reference code in a spread spectrum receiver and the spreading sequence that has been used in the transmitter to spread the information bits. Usually, code synchronization is achieved in two stages: a) code acquisition and b) code tracking. Acquisition is the process of initially attaining coarse alignment (typically within ± half of the chip duration), while tracking ensures that fine alignment within a chip duration is maintained. In this lesson, we primarily discuss about some concepts of code acquisition.

Code Acquisition Schemes

Acquisition is basically a process of searching through an uncertainty region, which may be one-dimensional, e.g. in time alone or two-dimensional, viz. in time and frequency (if there is drift in carrier frequency due to Doppler effect etc.) – until the correct code phase is found. The uncertainty region is divided into a number of cells. In the one-dimensional case, one cell may be as small as a fraction of a PN chip interval.

The acquisition process has to be reliable and the average time taken to acquire the proper code phase also should be small. There may be other operational requirements depending on the application. For example, some systems may have a specified limit in terms of the time interval 'T' within which acquisition should be complete. For such systems, an important parameter that may be maximized by the system designer is Prob ($t_{acq} \leq$ T). However, for other systems, it may be sufficient to minimize the mean acquisition time E[t_{acq}].

A basic operation, often carried out during the process of code acquisition is the correlation of the incoming spread signal with a locally generated version of the spreading code sequence (obtained by multiplying the incoming and local codes and accumulating the result) and comparing the correlator output with a set threshold to decide whether the codes are in phase or not. The correlator output is usually less than the peak autocorrelation of the spreading code due to a) noise and interference in the received signal or b) time or phase misalignment or c) any implementation related imperfections. If the threshold is set too high (equal or close to the autocorrelation peak), the correct phase may be missed i.e. probability of missed detection (P_M) is high. On the other hand, if the threshold is set too low, acquisition may be declared at an incorrect phase (or time instant), resulting in high probability of false acquisition (P_{FA}). A tradeoff between the two is thus desired.

There are several acquisition schemes well researched and reported in technical publications. Majority of the code acquisition schemes can be broadly classified according to a) the detector structure used in the receiver (**Fig. 7.39.1**) and b) the search strategy used (**Fig.7.39.2**).

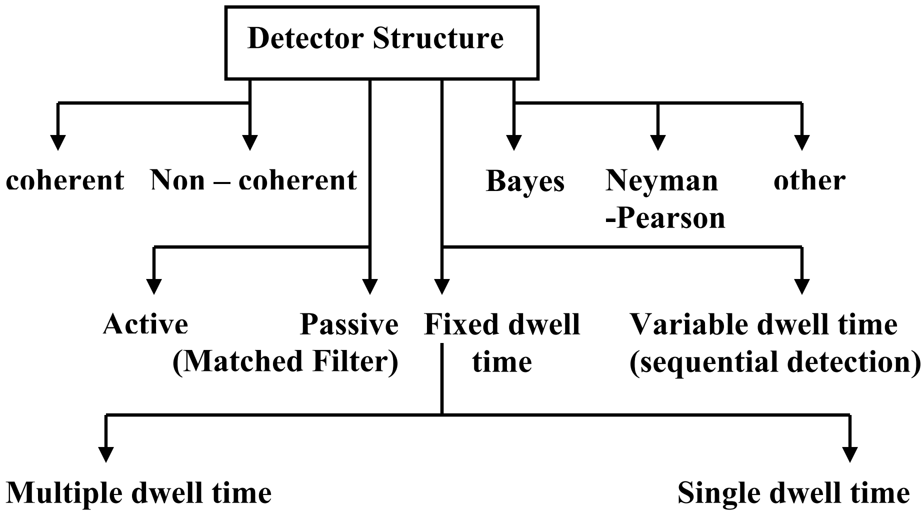

Fig.7.39.1 *Classification of detector structures used for code acquisition on DS-SS systems*

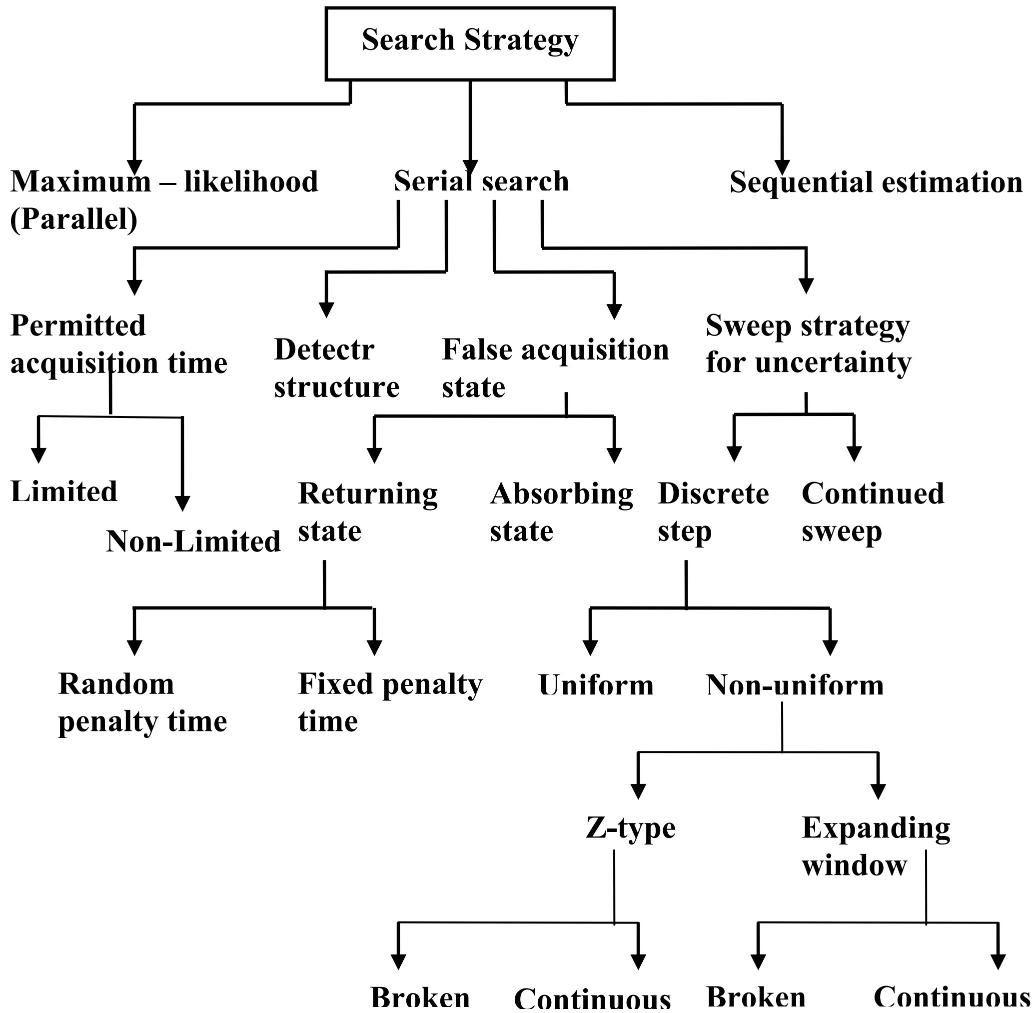

Fig. 7.39.2 *Classification of acquisition schemes based on search strategy*

The detector structure may be coherent or non-coherent in nature. If the carrier frequency and phase are not precisely known, a non-coherent structure of the receiver is preferred. **Fig 7.39.3** shows a coarse code acquisition scheme for a non-coherent detector.

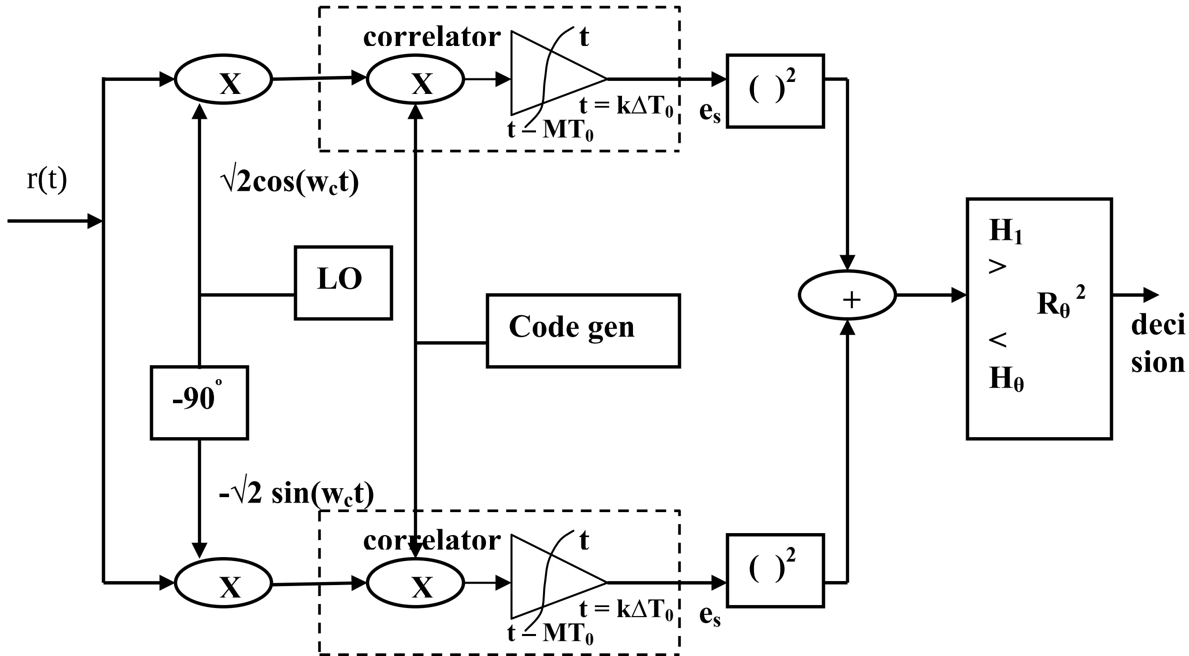

Fig. 7.39.3 *Structure of a non-coherent detector*

A code acquisition scheme may also be active or passive. In a receiver employing active code acquisition (sometimes called code detection), portions of the incoming and the local codes (a specific phase shifted version) are multiplied bit by bit and the product is accumulated over a reasonable interval before comparison is made against a decision threshold. If the accumulated value does not exceed the threshold, the process is repeated with new samples of the incoming code and for another offset version of the local code.

A passive detector, on the other hand, is much like a matched filter with the provision to store the incoming code samples in a shift register. With every incoming chip, a decision is made (high decision rate) based on a correlation interval equal to the length of the matched filter (MF) correlator. A disadvantage of this approach is the need for more hardware when large correlation intervals are necessary.

Code acquisition schemes are also classified based on the criterion used for deciding the threshold. For example, a Bayes' code detector minimizes the average probability of missed detection while a Neyman Pearson detector minimizes the probability of missed detection for a particular value of P_{FA}.

The examination or observation interval is known as 'dwell time' and several code acquisition schemes (and the corresponding detectors) are named after the dwell time that they use (**Fig.7.39.1**). Detectors working with fixed dwell times may or may not employ a verification stage (multiple dwell times). A verification process enhances the reliability of decision and hence is incorporated in many practical systems.

Classification based on search strategy

As noted earlier, the acquisition schemes are also classified on the basis of the search strategy in the region of uncertainty (**Fig 7.39.2**). Following the maximum likelihood estimation technique, the incoming signal is simultaneously (in parallel) correlated with all possible time-shifted versions of the local code and the local code phase that yields the highest output is declared as the phase of the incoming code sequence. This method requires a large number of correlators. However, the strategy may also be implemented (somewhat approximately) in a serial manner, by correlating the incoming code with each phase-shifted version of the local code, and taking a decision only after the entire code length is scanned. While one correlator is sufficient for this approach, the acquisition time increases linearly with the correlation length. Further, since the noise conditions are usually not the same for all code phases, this approach is not strictly a maximum likelihood estimation algorithm.

Another search strategy is sequential estimation. This is based on the assumption that, in the absence of noise, if 'n' consecutive bits of the incoming PN code (where "n" is the length of the PN code generator) are loaded into the receivers code generator, and this is used as the initial condition, the successively generated bits will automatically be in phase with the incoming ones. Cross correlation between the generated and incoming codes is done to check whether synchronization has been attained or not. If not, the next n bits are estimated and loaded. This algorithm usually yields rapid acquisition and hence is called the RASE (Rapid Acquisition by Sequential Estimation) algorithm. However, this scheme works well only when the noise associated with the received spread signal is low.

An important family of code acquisition algorithms is known as Serial Search. Following the serial search technique, a group of cells (probable pockets in the uncertainty region) are searched in a serial fashion until the correct cell (implying the correct code phase) is found. This process of serial search may be successful anywhere in the uncertainty region and hence the average acquisition time is much less than that in the maximum likelihood estimation schemes, though a maximum likelihood estimation scheme yields more accurate result. Incidentally, a serial search algorithm performs better than RASE algorithm at low CNR. Serial search schemes are also easier to implement. In the following, we briefly mention a practical code search techniques known as 'Subsequence Matched Filtering'.

Proposed in 1984, this is a rapid acquisition scheme for CDMA systems, that employs Subsequence Matched Filtering (SMF). The detector consists of several correlator based matched filters, each matched to a subsequence of length M. The subsequence may or may not be contagious, depending on the length of the code and the hardware required to span it. With every incoming chip of the received waveform, the largest of the SMF value is compared against a pre-selected threshold. Threshold exceedance leads to loading that subsequence in the local PN generator for correlation over a longer time interval. If the correlation value does not exceed a second threshold, a negative feedback is generated, and a new state estimate is loaded into the local generator. Otherwise, the PN generation and correlation process continues. ***Fig. 7.39.4*** shows the structure of a Subsequence Matched Filter based code acquisition process.

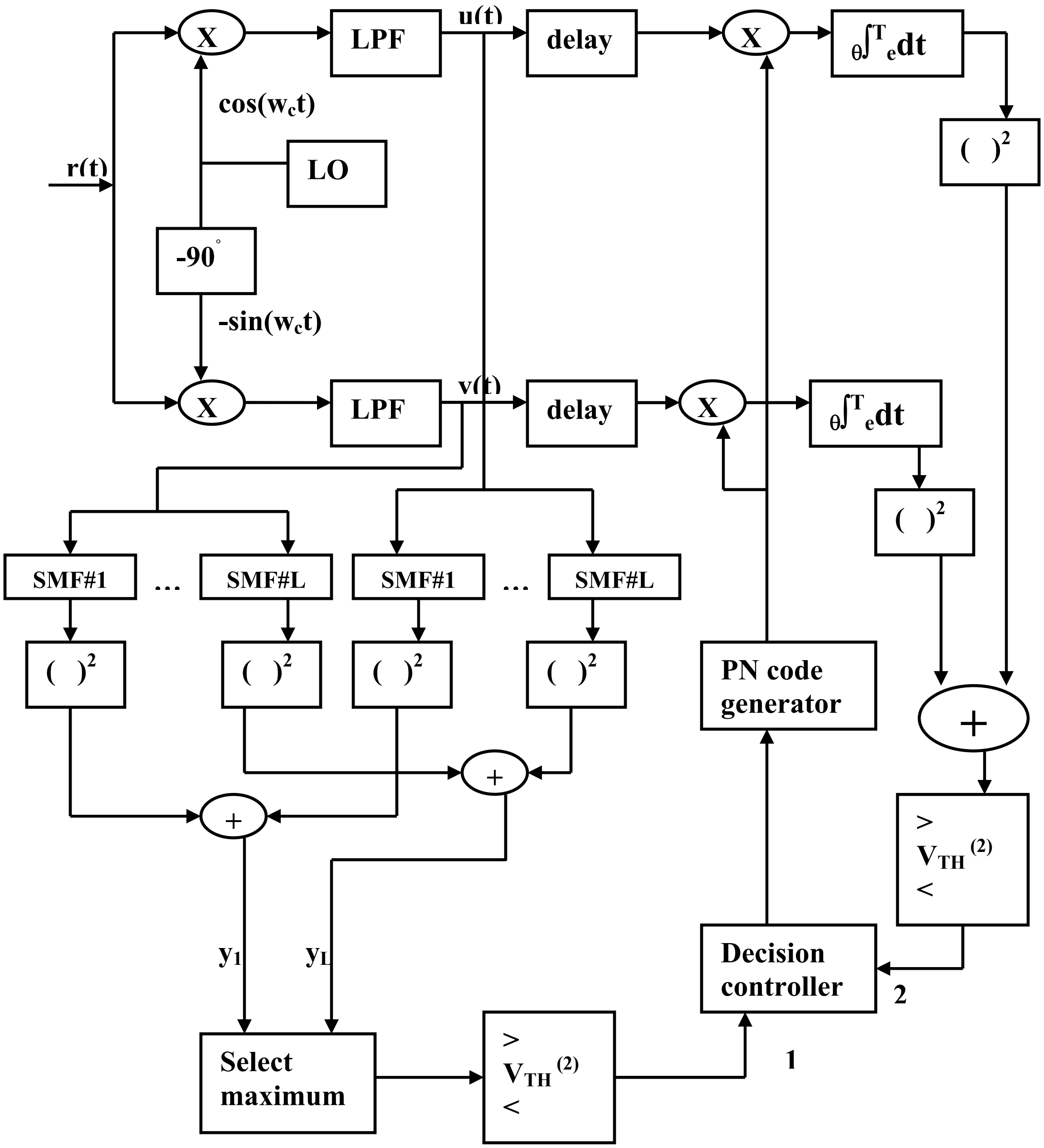

Fig. 7.39.4 *Structure of a Subsequence Matched Filter based code acquisition process*

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