Unit - 3 SYNCHRONISATION

Introduction :-

→ When the events in one sequence and corresponding events in the other occur simultaneously.

→ The process of making a situation synchronous and maintaining it in this condition is called "SYNCHRONIZATION"

Carrier Synchronization :-

When coherent detection is used, knowledge of both the frequency and phase of carrier is necessary. The estimation of carrier phase and frequency is called "CARRIER RECOVERY" (or) "CARRIER SYNCHRONIZATION".

Symbol Synchronization :-

→ To perform demodulation, the Rx has to know the instants of time at which the modulation can change its state.

→ ie, it has to know the starting & finishing times of the individual symbol, so that it may determine when to sample & when to quench the product integrators. The estimation of these times is called "CLOCK RECOVERY" or "SYMBOL SYNCHRONIZATION".

RECEIVER SYNCHRONIZATION :-

→ All DC systems require some degree of Synchronization to incoming S/l's by the Rx.

→ Some degree of Symbol Synchronization is reqd. for all digital comm. reception, either coherent or non-coherent.

FREQUENCY & PHASE SYNCHRONIZATION :-

→ All Synchronization circuits is some version of Phase Locked Loop (PLL)

→ PLL are Servo control loops, whose controlled Parameter is the phase of a locally generated replica of the incoming carrier S/l.

→ PLL has 3 basic components,

* phase detector
* a loop filter
* a Voltage controlled oscillator (VCO).

→ A phase detector is a device that produces a measure of the difference in phase betn an incoming S/l and the local replica.

→ When both these S/l's change with respect to each other, the phase difference becomes a time varying s/l in the loop filter.

→ The loop filter governs the PLL's response to these variations in the error s/l.

→ A VCO is the device that produces the carrier replica. The VCO, as the name implies, is a sinusoidal oscillator whose freq. is controlled, by a voltage level at the device i/p.

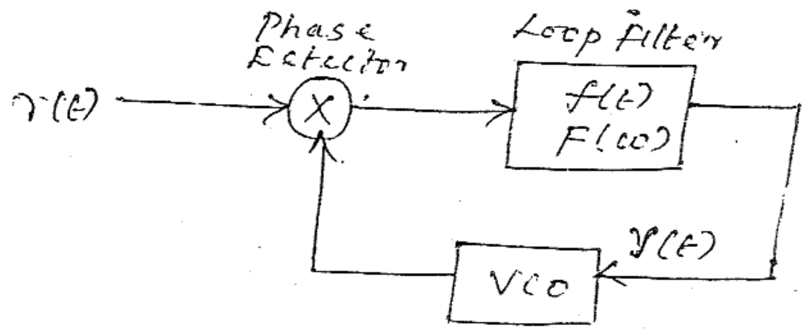


Fig :- Schematic of the basic PLL.

→ A positive i/p voltage will cause the VCO o/p freq. to be greater than its uncontrolled value ω_0, while a negative voltage will cause it to be less.

→ Phase lock is achieved by feeding a filtered version of the phase difference (ie, the phase error) betn the incoming s/l r(t) and the o/p of the VCO x(t), back to the i/p of the VCO y(t).

→ The VCO may not appear to be a sinusoidal oscillator, but it may be implemented as a read-only memory whose pointer are controlled by a combination of a clock and the o/p of the error estimator.

→ The f/b path may not be continuous but phase corrections may only be applied once per frame.

Consider a normalized input signal of the form,

$$r(t) = \cos[\omega_0 t + \theta(t)] \quad \text{—— (1)}$$

where, ω_0 - Normal carrier frequency.

$\theta(t)$ - slowly varying phase.

Consider a normalized VCO o/p of the form,

$$x(t) = -2\sin[\omega_0 t + \hat{\theta}(t)] \quad \text{—— (2)}$$

These s/e's will produce an o/p error signal at the phase detector o/p of the form,

$$e(t) = x(t)\, r(t)$$

$$= 2\sin[\omega_0 t + \hat{\theta}(t)]\cos[\omega_0 t + \theta(t)]$$

$$= \sin[\theta(t) - \hat{\theta}(t)] + \sin[2\omega_0 t + \theta(t) + \hat{\theta}(t)] \quad \text{—— (3)}$$

Assuming the loop filter is low pass, the 2nd term on the RHS of eqn (3) will be filtered out and can be ignored.

→ The LPF provides an error s/e ie, a function of the difference in phases betn the i/p and VCO o/p.

→ The o/p freq. of VCO is a linear function of i/p voltage.
→ Therefore, an i/p voltage of zero produces an o/p freq. of ω_0, the difference in the o/p freq. from ω_0 will be proportional to the value of i/p voltage $y(t)$ or,

$$\Delta\omega(t) = \frac{d}{dt}[\hat{\theta}(t)] = K_0 y(t)$$

$$= K_0 e(t) * f(t)$$

$$= K_0 [\theta(t) - \hat{\theta}(t)] * f(t)$$

→ where, $\Delta\omega(t)$ – frequency difference

K_0 – Gain of the VCO,

$f(t)$ – Loop filter impulse response.

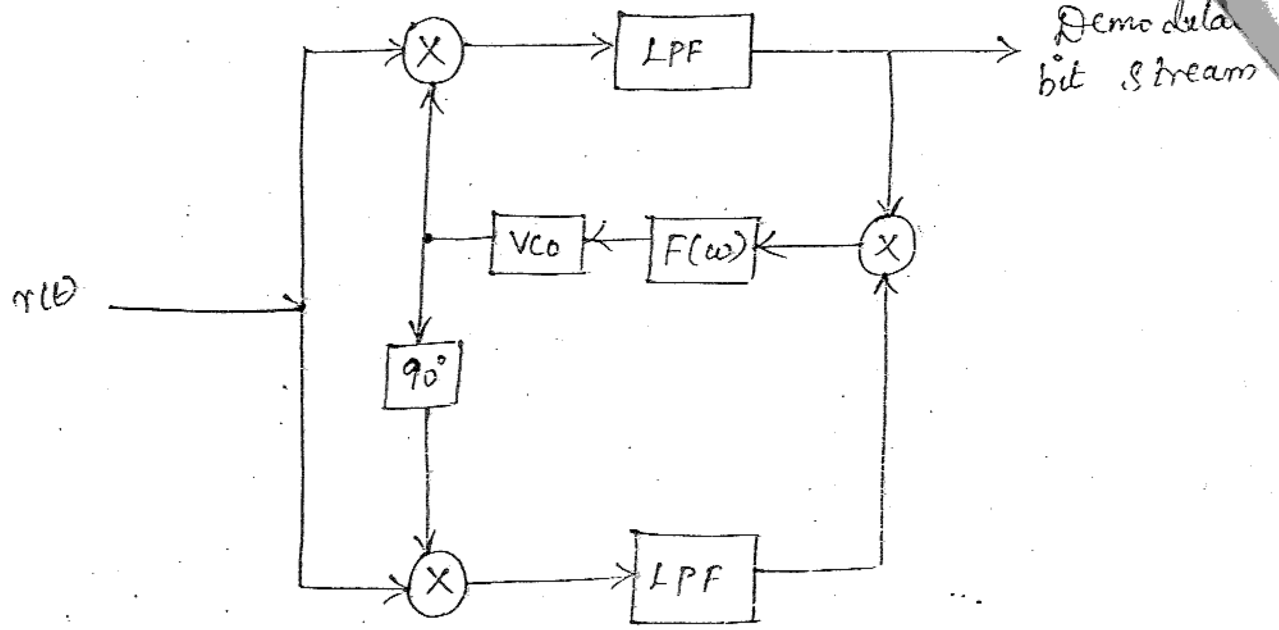
→ This linear differential eqn. in $\theta(t)$ is known as the linearized loop equation.

COASTAS LOOP :-

→ An important form of a suppressed carrier loop is the costas loop.

→ This loop is important b'cos it eliminates the square-law device, which can be difficult to implement at carrier frequencies.

→ The problem with costas loop is to achieve, the theoritically optimum performance, the 2 loop filters must be perfectly matched.



→ If the arm filters are implemented digitally, there will be no problem keeping them matched.

→ This design decision will depend on the parameters and requirements of the particular receiving system and cannot be generalized here.

SYMBOL SYNCHRONIZATION :-

All digital receivers need to be synchronized to the incoming digital symbol transitions in order to achieve optimum demodulation. This results to the technique known as Symbol Synchronization or Data Synchronization.

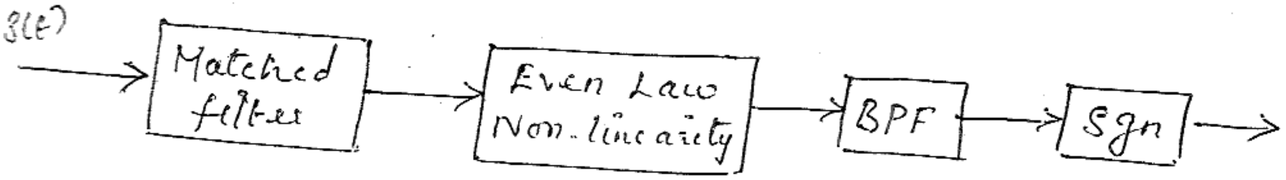
Open Loop Symbol Synchronization :-

→ Symbol Synchronization is also called non linear filter synchronizers.

→ It generates a frequency component at the symbol rate by operating a combination of filtering and a non-linear device.

Three examples of open-loop bit synchronizer is shown.

→ In the first example, the incoming s/l s(t) is filtered with a matched filter.



→ The o/p of this filter will be the autocorrelation function of the i/p signal shape.

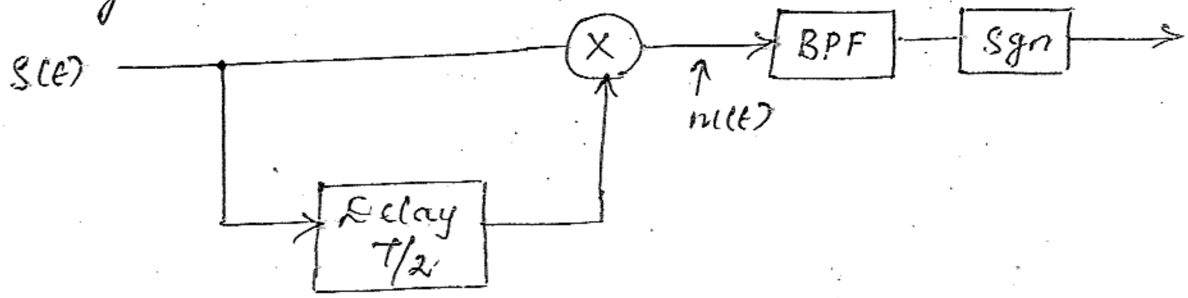
→ The sequence of bit autocorrelation waveshapes is then rectified by some type of memoryless even-law non-linearity.

→ Thus the o/p waveform from the even-law device will contain a fourier component at the fundemental frequency of the data clock.

→ This freq. component is isolated from its harmonics with a BPF and shaped with an ideal saturating amplifier, with transfer function

$$Sgn\ x = \begin{cases} 1 & \text{for } x > 0 \\ -1 & \text{otherwise} \end{cases}$$

→ The Second example produces a fourier com[illegible] at the data clock frequency by means of a delay and multiply.



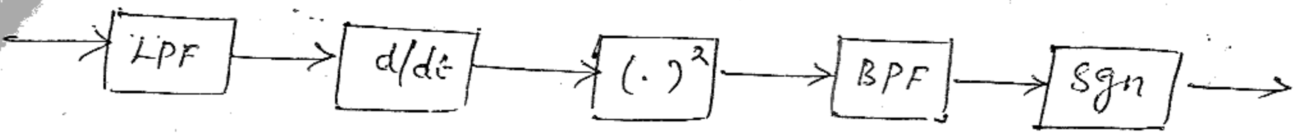
→ The waveform m(t) will always be positive in the second half of every bit period, but will have a negative first half if there has been a state change in the incoming bit stream S(t).

→ This produces a square - wave s/l with spectra[illegible] components at the data rate & all harmonics.

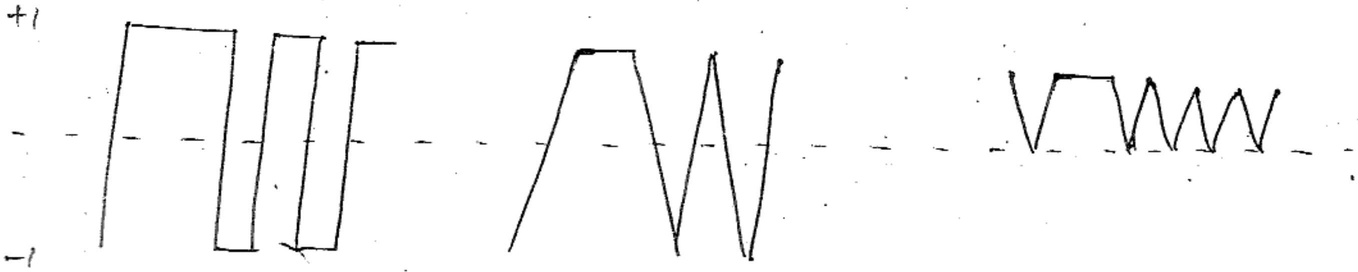
→ The final example amounts to an edge detecto[illegible]

→ The main operations are those of differentiat[illegible] and rectification.

→ For a square wave i/p, the differentiator will produce positive or negative spikes at all symbol transitions.



→ When rectified, the resulting sequence of positive spikes will have a fourier component at the data symbol rate.



Incoming Binary Signal | output of Matched Filter | output of even-law non linearity

Fig :- Open-loop bit synchronizer illustration.

CLOSED - LOOP SYMBOL SYNCHRONIZATION :-

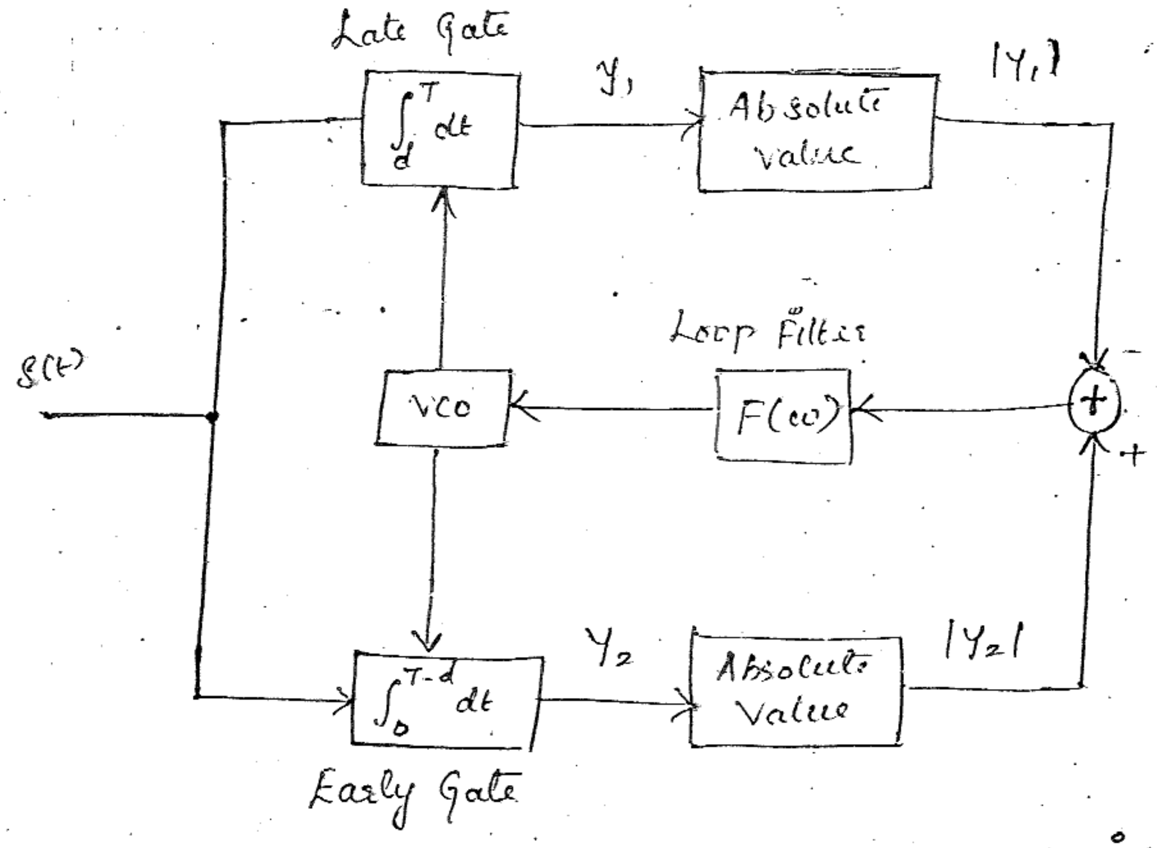
→ Closed-loop symbol synchronizer is the early/late-gate synchronizer.

→ The synchronizer operates by performing two seperate integrations of the incoming s/l energy over two different (T-d) second portion of a symbol interval.

→ The first integration begins integrations at the loop's best estimate of the beginning of a symbol period.

(T-d) Second

→ The second integral delays the start of its integration for 'd' seconds and then integrates to the end of the symbol period.



→ When the device is synchronized, it is stable - there's no tendency to drive itself away from synchronization.

→ In the first portion of the early gate falls in the previous bit interval, while the late gate is still entirely inside the current symbol.

→ The late-gate integrator will accumulate signal over its entire (T-d) integration interval.

→ The error s/l will be $e = -2\Delta$, which will lower the i/p voltage to the VCO.

→ This will reduce the VCO o/p freq. & retard the Rx's timing to bring it back towards the incoming s/l's bit timing.

SYNCHRONIZATION WITH CONTINUOUS-PHASE MODULATIONS (CPM) :-

synchroni with

Background :-

→ Continuous-phase modulations (CPM) have grown from a research topic to an increasingly important signaling technique b'cos of their BW efficiency.

signal import

→ As BW becomes increasingly, their importance will continue to increase.

→ The BW efficiency of CPM is obtained by increasing the smoothness of the waveform in the time domain.

smoothney

A normalized CPM s/l can be represented in complex notation as,

$$s(t) = \exp\{j[\omega_0 t + \theta + \psi(t-\tau, \alpha)]\}$$

Where, ω_0 - carrier frequency.

θ - carrier phase

$\psi(t, \alpha)$ - excess phase of $s(t)$

$\exp\{j[\omega_0 t + \theta + \psi(t-$

$[\tau, \alpha$

There are 3 techniques involved in CPM Signa

(i) use signal pulses that have several orders of continuous derivatives.

(ii) Allow individual S/e pulses to occupy multiple S/e time intervals.

(iii) Reduce the maximum allowed phase change per symbol interval.

Data - Aided Synchronization :-

→ Techniques for synchronizing CPM receivers can be divided into those that rely on knowledge of the information symbols & that those that do not. Those that rely on such knowledge are called data - aided technique.

2 ways in which the data symbols could be known,

(i) Either symbols under consideration are a part of a known header (or)

(ii) Training sequence inserted into the data stream.

Non-data-Aided Synchronization :-

→ One of the first tenets of Information theory is that having more information is better than having less.

→ The symbol sequence will allow better estimates of carrier phase & symbol timing than not knowing.

→ In this cases, non-data-aided (NDA) synchronization process are called are called for, two techniques of general applicability.

→ The first technique is a direct extension of the development in the previous section.

If the symbol sequence (c_K, α_K) is not known, a new likelihood function

$$\Lambda(R|\hat{\theta};\hat{\tau}) = \exp\left\{\sum_{K=0}^{L_0-1} Re\left[Z_K(c_K, \alpha_K, \hat{\tau})\, e^{-j(\hat{\theta}+\phi_K)}\right]\right\}$$

Since, the likelihood function is proportional to a conditional probability, the chain rule of conditional probabilities can be applied to get back to a likelihood function dependent on $\hat{\theta}$ and $\hat{\tau}$.

The chain rule states that,

$$P(r(t) = R(t)|\gamma) = \int_{\text{all } \beta} P[r(t) = R(t)|\gamma, \beta]\, P(\beta)\, d\beta.$$

FRAME SYNCHRONIZATION :-

→ Almost all digital data streams have some sort of frame structure.

→ If the data stream is digitized TV, each pixel is represented by a word having several bits.

→ Computer data are typically organized into words of some number of 8-bit bytes and organized into card images, packets, frames or files.

→ For a R_x to make sense of the incoming data stream, it needs a frame structure.

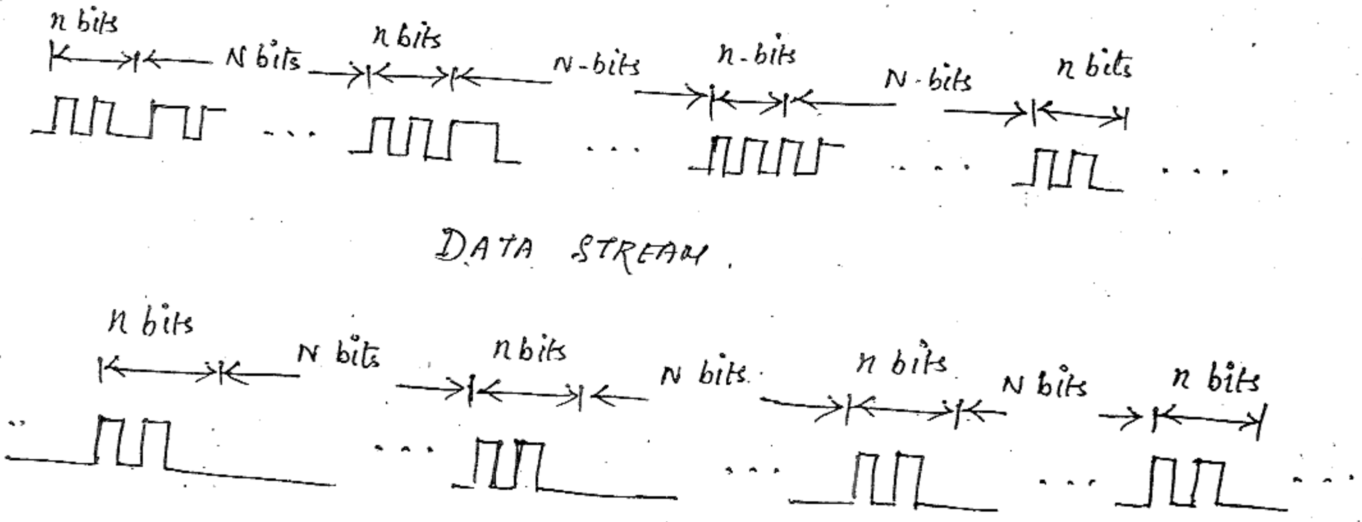
→ Frame synchronization is usually accomplished with the aid of some special signalling procedure from the T_x.

→ The frame marker is a single bit, or a short pattern of bits that the T_x injects periodically into the data stream.

→ The R_x must know the pattern and the injection interval.

→ When the R_x comes into frame synch. however, the correction should nearly be perfect, blemished with an occasional detection error.

→ If the R_x is not in synchronization with the framing pattern, the accumulated correlation will be low.



RECEIVER GENERATED FRAME MARKER REPLICA

Fig :- FRAME MARKER ILLUSTRATION

Advantages :-

→ The advantage of the frame marker is its simplicity.

→ Even a single bit can suffice as a frame marker if a sufficient number of correlations are accumulated

Drawbacks :-

→ If the sufficient number is too large, & thus the expected time reqd. to acquire synchronization would be long.

→ The inserted bits may make the organization of the data stream awkward.

A good synchronization codeword is one that has the property that the absolute value of its "Correlation sidelobes" is small.

→ A correlation sidelobes is the value of the correlation of a codeword with a time-shifted version of itself.

→ Thus, the correlation sidelobe value for a k-symbol shift of an N-bit code sequence $\{x_i\}$ is

$$C_k = \sum_{j=1}^{N-k} x_j \, x_{j+k}.$$

→ The sidelobe correlation properties of Barker codes are based on the assumption that the adjacent symbols have zero values.

→ This approximation will takes a value of ±1.

Barker Synchronization Codewords

N	Barker Sequence.
1	+
2	++ (or) + −
3	++ −
4	+++ − (or) ++ − +
5	+++ − +
7	+++ − − + −
11	+++ − − − + − − + −
13	++ +++ − − ++ − + − +

→ Two probabilities characterize the performance of a system using a synchronization word, namely,

(i) Probability of a missed detection.

(ii) Probability of a false alarm.

→ In order to decrease the probability of a miss, the system design may allow less-than-perfect correlation of an incoming synchronization word.

The probability of a miss for an N-bit word is given by,

$$P_m = \sum_{j=k+1}^{N} \binom{N}{j} p^j (1-p)^{N-j}$$

Where, p - Probability of a detector bit error.

The Probability of a false alarm generated by N bits of random data is given by,

$$P_{FA} = \sum_{j=0}^{k} \frac{\binom{N}{j}}{2^N}.$$

→ It can be seen that for small p, P_m will decrease roughly exponentially with increasing k.

→ Unfortunately, P_{FA} increases roughly exponentially will increasing k.

NETWORK SYNCHRONIZATION :-

→ For systems using coherent modulation technique, one-direction communications such as broadcast channels or single-link communications makes the synchronization totally a receiver function.

→ Satellite communication systems makes sense for synchronization to be mostly or entirely a terminal function.

→ This systems uses TDMA, which is allotted a segment of time in which to transmit its information.

→ Synchronization of the terminal Tx also makes sense with system that combines signal processing at the central node with FDMA.

→ Tx Synch. procedure may be classified by either open loop or closed loop.

→ Open loop techniques rely on link parameters being accurately known and predictable.

→ Open loop technique do not rely on any measurements of the arrival singnal parameters at the central node.

→ The links themselves operate continually for relatively long periods once established.

→ A closed loop technique requires a return path that provides a response to the terminal's transmission.

Open-Loop Transmitter Synchronization :-

→ Open loop systems were further classified into
(i) Systems that employ information gained by observing a return link
(ii) The systems those do not employ the return link, which is simplest of real-time processing requirements

→ All Tx synch. will precorrect the timing and transmission frequency of the s/l at the Rx with expected time and frequency.

→ By transmitting the s/l early, it will arrive at the Rx at a time.

The time of arrival at the node is given by,

$$T_A = T_t + \frac{d}{c}$$

where, T_t - actual transmission start time
d - Transmit distance
c - Speed of light.

To be received correctly, the reqd. transmission radian frequency is,

$$\omega \approx \left(1 - \frac{V}{c}\right) \omega_0$$

where, c - Speed of light
V - Relative velocity.
ω_0 - normal transmission radian frequency.

→ But, neither the time nor the frequency Precorre[ction]
can be done exactly.

→ There will always be some time & frequency precorrection error.

The time error may be expressed as,

$$T_e = \frac{r_e}{c} + \Delta t.$$

where, r_e - error in the range estimate

Δt - diff betn the ref. time at the terminal & the Rx.

The frequency error may be expressed as,

$$\omega_e = \frac{V_e \omega_0}{c} + \Delta \omega$$

where, V_e - error is the predicted relative velocity of Tx or Rx.

$\Delta \omega$ - freq. diff betn Tx & Rx freq. reference.

Advantages :-

(i) The acquisition is fast.

(ii) The amount of real-time computation reqd. is small.

Disadvantages :-

(i) It requires the existence of external authority which are relatively inflexible.

(ii) The system cannot adjust quickly to any unplanned change in conditions.

Closed-Loop Transmitter Synchronization :-

→ It involves the transmission of special synchronization s/l's that are used to determine the s/l's time or frequency error related to the Rx.

→ If the central node has sufficient processing capacity, the central node may make an actual error measurement.

→ It can be formatted or returned to the Tx on a return link.

→ The BFSK transmission to a central node makes the non-coherent bit decisions.

→ If the T_x^d s/l is an alternating sequence, the s/l at the central node can be modeled as,

$$r(t) = \begin{cases} \sin[(\omega_0 + \omega_s + \Delta\omega)t + \theta & ; 0 \le t \le \Delta t \\ \sin[(\omega_0 + \Delta\omega)t + \theta & ; \Delta t < t \le T. \end{cases}$$

The detected signal energy can be expressed as,

$$z^2 = x^2 + y^2$$

Where,

$$x = \frac{1}{T}\int_0^T r(t)\cos\omega_0 t \, dt$$

$$y = \frac{1}{T}\int_0^T r(t)\sin\omega_0 t \, dt.$$

Thus,

$$Z^2 = \left(\frac{\sin[(\omega_s + \Delta\omega)\,\Delta t/2]}{(\omega_s + \Delta\omega)T}\right)^2 + \left(\frac{\sin[\Delta\omega(T - \Delta t)/2]}{\Delta\omega T}\right)^2$$

$$+ \frac{\cos(\Delta\omega \Delta t) + \cos[\Delta\omega T - (\omega_s + \Delta\omega)\,\Delta t] - \cos(\Delta\omega T) - \cos(\omega_s \Delta t)}{2\,\Delta\omega(\omega_s + \Delta\omega)\,T^2}$$

For special cases, where the time error, Δt is zero, we get,

$$Z^2 = \left[\frac{\sin(\Delta\omega T/2)}{\Delta\omega T}\right]^2$$

Advantages :-

→ The error measurements that are transmitted on the return link can be a short digital sequence.

→ The response of the processor is quick.

→ The central node may not be easily accessible, and reliability may dictate a simple design.

Disadvantage :-

→ The inefficient use of the return channel & that the return s/l may be difficult to interpret.

UNIT - 4 SPREAD SPECTRUM TECHNIQUES :-

SPREAD SPECTRUM :-

If the transmission BW employed is much greater than the minimum BW required to transmit the information, then the technique is known as "Spread Spectrum Technique".

Requirements :-

The system is said to spread spectrum if it fulfills the following requirements.

(i) The s/l occupies a BW much excess of the minimum BW to send the information.

(ii) Spreading signals often called a "Code Signal" is independent of the data.

ATTRIBUTES OF SPREAD SPECTRUM :-

⇒ Interference Suppression Benefits :-

→ Effective Communication is possible only with the interfering noise of infinite power.

→ B'cos the finite Power noise components that are Present within the s/l space can interfere with the s/l.

The effect of spectrum spreading in the presence of white noise with spreading an intentional jammer is shown.

Spread Spectrum in the Presence of White noise :-

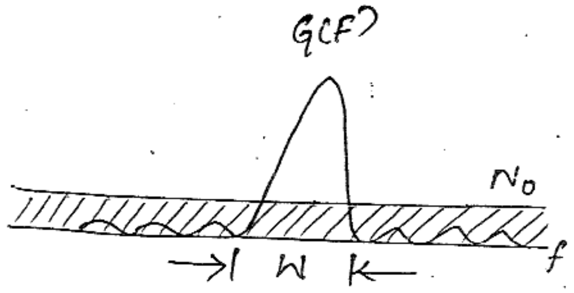


Fig : Before Spreading

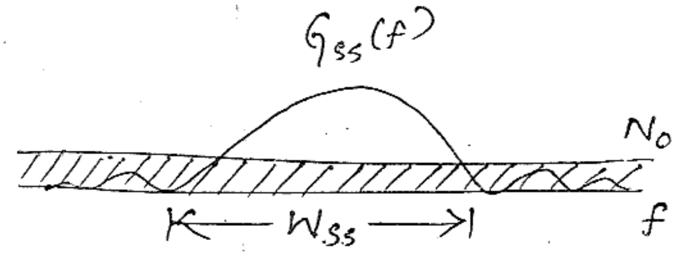


Fig : After Spreading

→ This implies that the single - sided power spectral density of white noise N_0, is unchanged as a result of expanding the s/e BW from W to W_{ss}

→ The average power of white noise is infinite.

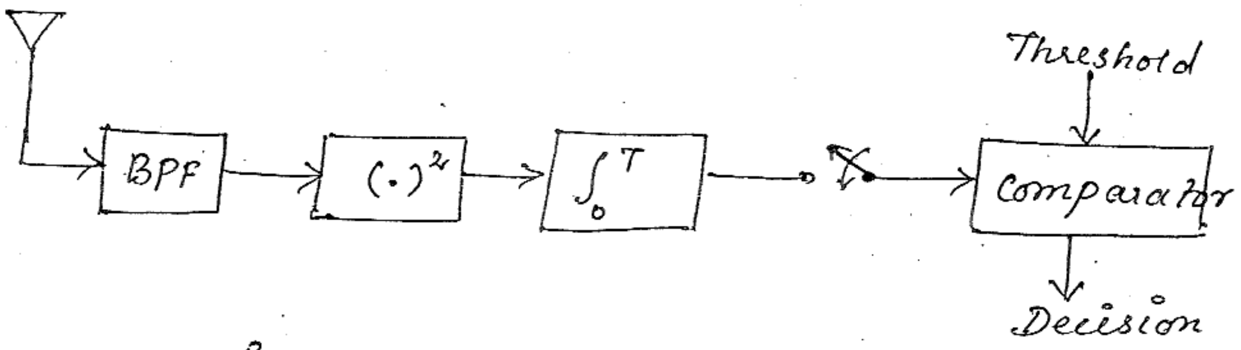
→ Hence, the use of spreading offers no performance improvement.

⇒ Energy Density Reduction :-

→ System designed for this task are known as "low probability of detection (LPD)" or low "probability of intercept (LPI) communication systems.

→ These s/s' are designed to make the detection of their s/e's as difficult as possible but the intended Rx.

→ A radiometer is a simple power measuring instrument that can be used to detect the presence of spread spectrum s/l within some BW.



→ It consists of BPF with BW 'W' and squaring circuit to ensure a positive o/p value with an integrated circuit.

→ At time $t = T$, the o/p of the integrator is compared to a preset threshold.

→ If the o/p of the integrator is larger than the threshold, a s/l is declared present otherwise the s/l is declared absent.

⇒ Fine Time Resolution :-

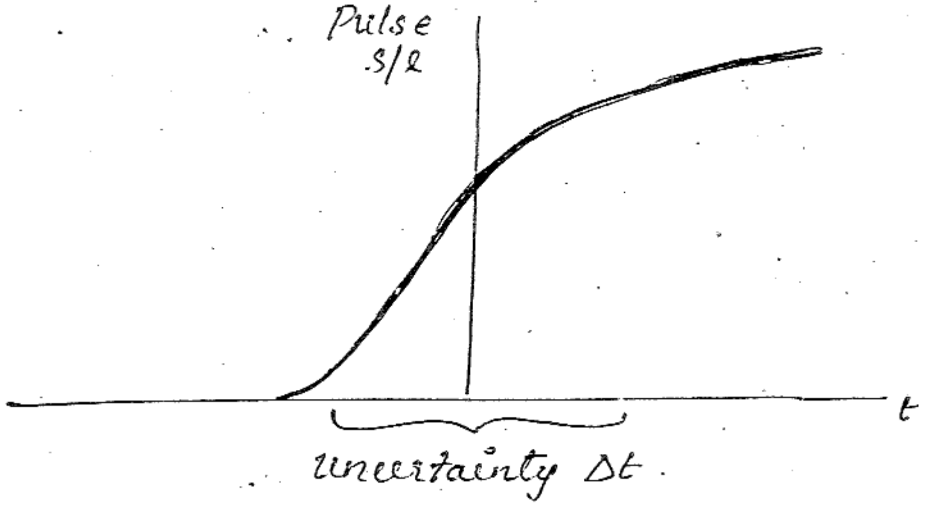
→ Spread-spectrum s/l's can be used for ranging or determination of position location.

→ Distance can be determined by measuring the time delay of a pulse as it traverses the channel.

→ The delay measurement is inversely proportional to the ~~ss~~ BW of the s/l pulse.

→ Δt is proportional to the rise time of the pu[lse] which is inversely proportional to the ~~rise time of the pulse~~ BW of the pulse s/l,

ie, $\Delta t = \frac{1}{W}$.



Δt = Rise time of pulse = $\frac{1}{W}$

fig :- Time delay Measurement.

⇒ Multiple Access :-

→ Spread Spectrum technique can be used as a multiple access technique to share a communication resources among numerous users.

→ CDMA employs a unique spread spectrum signaling code.

→ A type of multiple access is the ability to provide communication privacy betⁿ users with different spreading s/l's.

PSEUDONOISE SEQUENCES :-

→ The Spread-Spectrum approach called transmitted reference (TR) can utilize a truly random code s/e for spreading and despreading.

→ The stored reference (SR) approach cannot use a truly random code s/e since the code needs to be stored or generated at the Rx.

→ For the SR system, a pseudonoise or pseudorandom code s/e must be used.

→ However the pseudorandom s/e is not random at all, it is a deterministic.

→ Even though the s/e is deterministic, it appears to have the statistical properties of sampled white noise.

→ It appears to an unauthorized listener, to be a truly random s/e.

RANDOMNESS - PROPERTIES :-

→ There are 3 basic properties that can be applied to any periodic binary sequence as a test for the appearance of randomness.

→ The properties called balance, run, and correlation are described for binary signals as follows.

Balance Property :-

→ Good balance requires that in each period of the sequence.

→ The no. of binary ones differs from the number of binary zeros by at most one digit.

Run Property :-

→ A run is defined as a sequence of a single type of binary digits.

→ The appearance of the alternate digit in a sequence starts a new run.

→ The length of the run is the no. of digits in the run.

→ Among the runs of ones & zeros in each period, it is desirable that one-half the runs of each type are of length 1, about one-fourth are of length 2, one-eighth are of length 3, & so on.

Correlation Property :-

→ If a period of the sequence is compared term by term with any cyclic shift of itself.

→ The no. of agreements differs from the number of diagreements by not more than one count.

SHIFT REGISTER SEQUENCES :-

→ Consider a linear f/b shift register, made up of 4-stage register for storage and shifting.

→ ie, a module-2 adder and a f/b path from the adder to the i/p of the register.

→ The shift register operation is controlled by a sequence of clock pulse.

→ At each clock pulse the contents of each state in the register is shifted to the right.

→ At each clock pulse the contents of stages x_3 & x_4 are modulo-2 added & the result is fed back to stage x_1.

→ The shift register sequence is defined to be the o/p of the last stage, stage x_4.

→ Assume that stage x_1 is initially filled with a one and the remaining stages are filled with zeros.

→ ie, initial state of the register is 1000.

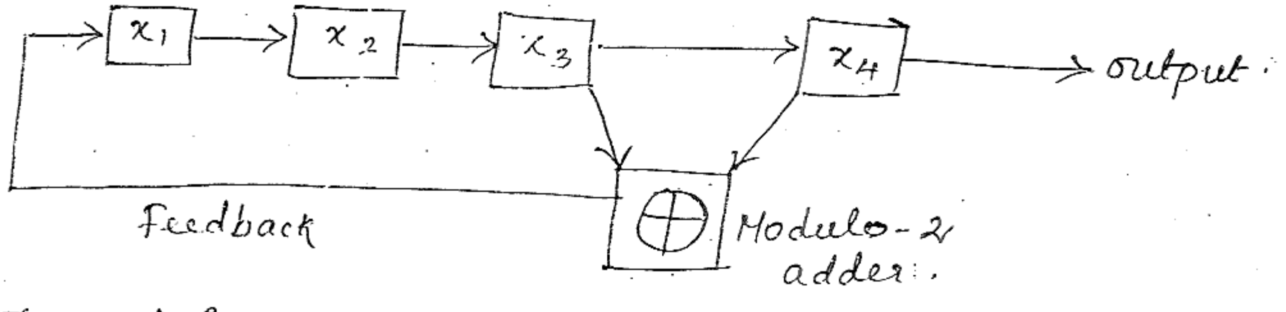


Fig :- Linear feedback shift register example.

1000 0100 0010 1001 1100 0110 1011 0101
1010 1101 1110 1111 0111 0011 0001 1000

→ Since the last State, 1000 Corresponds to initial State, the register repeats the foregoing sequence after 15 clock pulses.

→ The o/p sequence is obtained by noting the contents of stage x_4 at each clock pulse.

The o/p sequence is seen to be,

0 0 0 1 0 0 1 1 0 1 0 1 1 1 1

where the left most is the earliest bit.

→ Let us check the randomness properties outlined in the o/p.

→ first, balance property: There are 7 0's and 8 1's, ∴ the sequence meets the balance condition.

→ Next, run property: consider the '0' runs, there are 4 of them. One-half are of length 1 and one-fourth are of length 2.

→ The same is true for the one runs.

→ The sequence is too short to go further, but the run condition is met.

→ The o/p sequence have ~~pro~~ been classified as Maximal length or non-maximal length.

→ For maximal length, the period of clock pulse is $P = 2^n - 1$

→ If the length is less than $(2^n - 1)$, the sequence is non-maximal length.

DIRECT - SEQUENCE SPREAD - SPECTRUM SYSTEMS :-

→ Direct sequence is the name given to the spectrum spreading technique.

→ Here, a carrier wave is 1st modulated with a data s/l $x(t)$, then the data-modulated s/l is again modulated with a high-speed spreading s/l $g(t)$.

→ Consider a constant-envelope data-modulated carrier given by,

$$s_x(t) = \sqrt{2P}\cos[\omega_0 t + \theta_x(t)]$$

Where,

P - power,
ω_0 - radian frequency
$\theta_x(t)$ - data phase modulation.

→ With constant envelope mod'n, the transmitted waveform is given by,

$$s(t) = \sqrt{2P}\cos[\omega_0(t) + \theta_x(t) + \theta_g(t)]$$

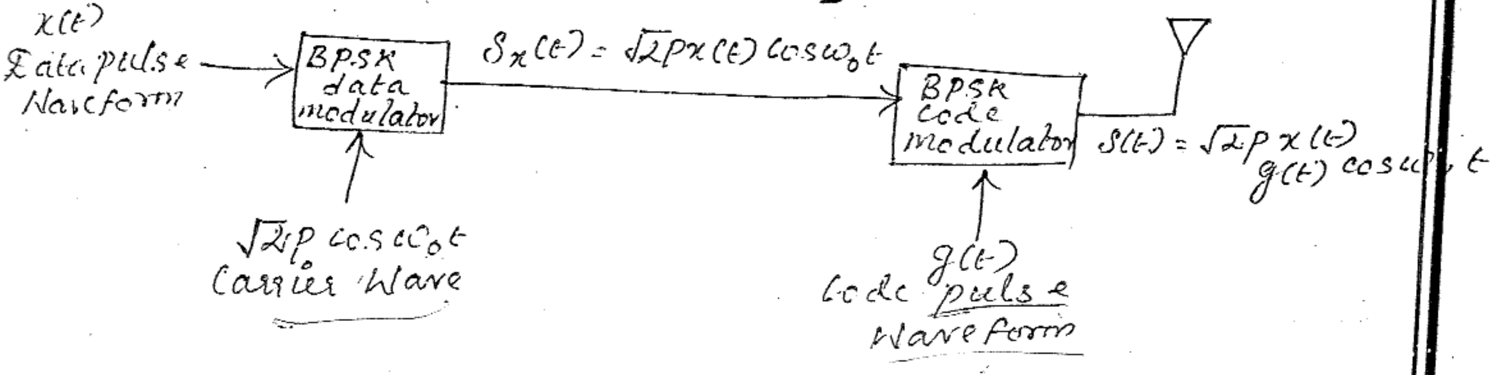


Fig : BPSK Direct Sequence Transmitter.

→ The data pulse stream and the spreading pulse stream are first multiplied, and then the composite $x(t)$ modulates the carrier.

Pulse Value	Binary Value
1	0
−1	1

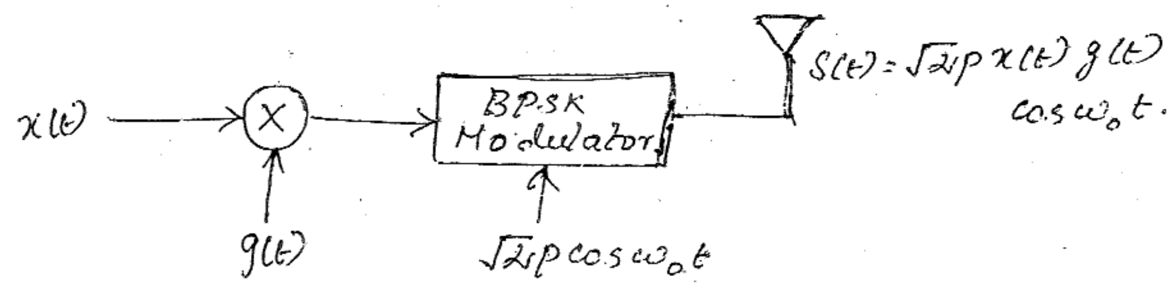


Fig:- Simplified BPSK direct - sequence transmitter.

→ If the assignment of pulse value to binary value is shown as above, then the initial step in the DS/BPSK modulation can be accomplished by modulo - 2 addition.

BPSK demodulation s/l is accomplished by correlating or re-modulating the received s/l with a synchronized replica of $g(t - \hat{T}_d)$.

Where, $\hat{T}_d$ - Rx estimate of propagation delay T_d.

→ In the absence of noise & interference, the o/p s/l from the correlator can be written as,

$$A \sqrt{2P}\, x(t - T_d)\, g(t - T_d)\, g(t - \hat{T}_d) \cos[\omega_0(t - T_d) + \phi]$$

Where, A - System gain parameter

ϕ - random phase angle in the range $(0, 2\pi)$

$$r(t) = A\sqrt{2p}\, x(t - T_d)\, g(t - T_d) \cos[\omega_0 (t - T_d) + \phi]$$

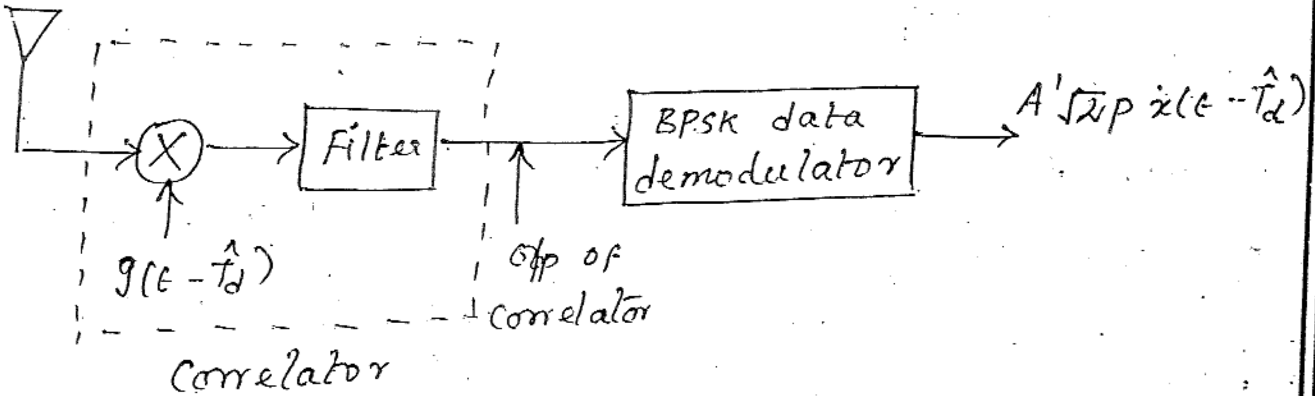


Fig : BPSK Direct sequence Receiver.

→ Since $g(t) = \pm 1$, the product $g(t - T_d)\, g(t - \hat{T}_d)$, will be unity if $\hat{T}_d = T_d$, is exactly synchronized with the code s/e at the Tx.

FREQUENCY HOPPING SYSTEMS :-

→ The modulation used with frequency Hopping (FH) technique is M-ary frequency shift keying (MFSK).

→ $K = \log_2 M$ information bits are used to determine one of M frequencies to be transmitted.

→ In a conventional MFSK system, the data symbol modulates a fixed frequency carrier in an FH/MFSK system.

→ The data symbol modulates a carrier whose frequency is pseudorandomly determined.

→ The FH modulation process can be of 2 methods,

(i) Data modulation

(ii) Frequency - hopping modulation.

→ Frequency synthesizer produces a transmission tone based on the PN code & the data.

→ The freq. hopping BW "W_{ss}" determines the minimum number of chips necessary in the frequency word.

→ The transmission BW is identical to the BW of conventional MSFK, which is smaller than W_{ss}.

→ Since, freq. hopping operates over a wide BW, it is difficult to maintain phase coherence from hop to hop.

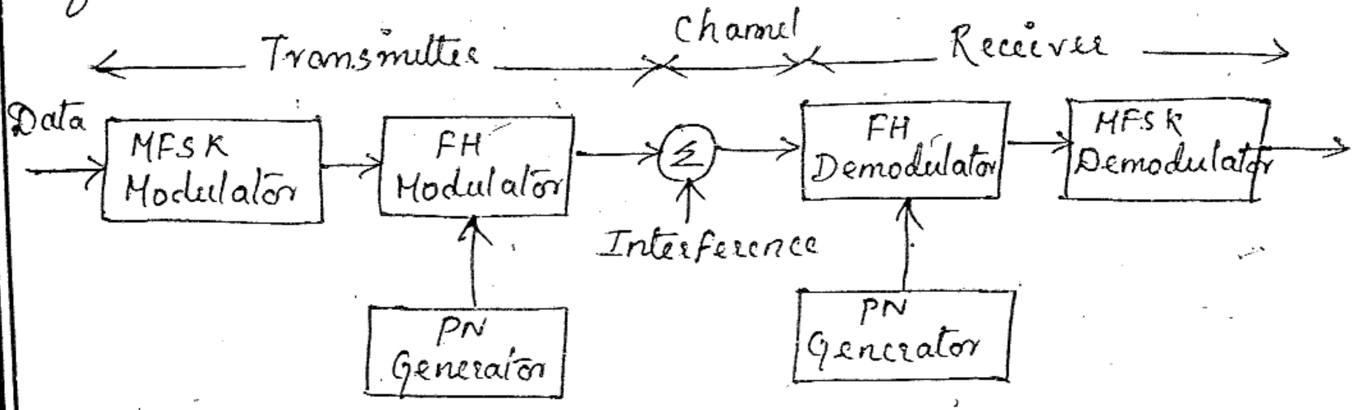


Fig :- FH/MFSK System.

→ The received S/l is first FH demodulated by mixing it with same sequence of pseudo-randomly selected freq. tones used for hopping.

→ Then the dehopped S/l is applied to a conventional bank of M non-coherent energy detectors to select the most likely symbol.

Frequency Hopping Example :-

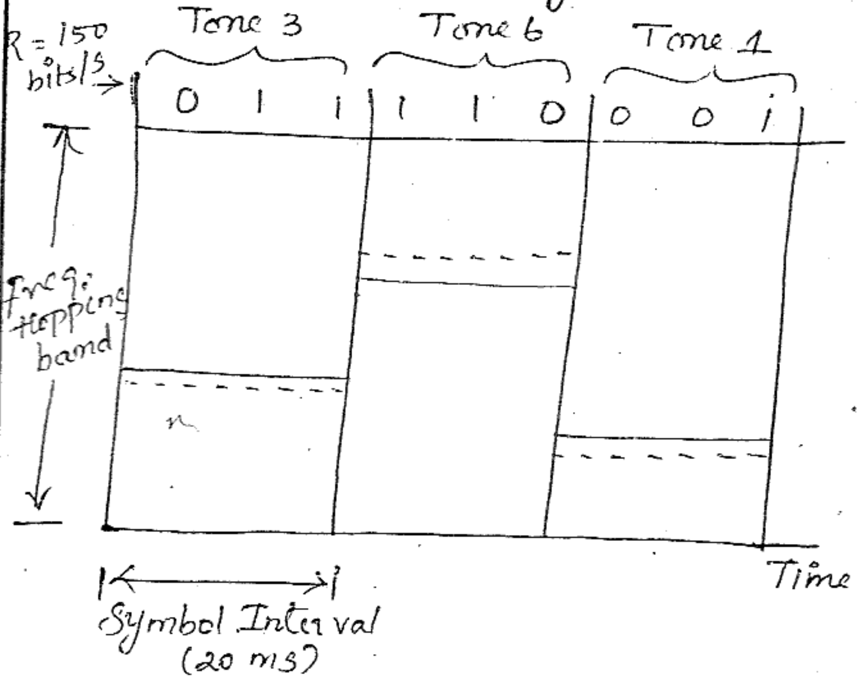
→ The i/p data consists of binary sequence with data rate of $R = 150$ bits/s.

→ The modulation is 8-ary FSK.

→ Thus, symbol rate is $R_s = R/(\log_2 8) = 50$ symbols/s. (Symbol duration $T = 1/50 = 20$ ms)

→ The frequency is hopped once per symbol, and the hopping is time synchronous with symbol boundaries.

→ Thus, the hopping rate is 50 hops/s.



Tone Number	Tone	Data Symbol
0	fo + 175 Hz	000
1	fo + 125 Hz	001
2	fo + 75 Hz	010
3	fo + 25 Hz	011
	fo	
4	fo − 25 Hz	100
5	fo − 75 Hz	101
6	fo − 125 Hz	110
7	fo − 175 Hs	111

→ The above fig, depicts the time-bandwidth plane of the communication resource.

→ The legend on the right side illustrates the set of 8-ary FSK symbol-to-tone assignments.

Robustness :-

→ A common dictionary definition describes the term "robustness" as the state of being strong and healthy; full of vigor; hardy.

→ In the state of communication, the usage is not too different.

→ Robustness characterizes a s/m's ability to withstand impairments from the channel, such as noise, jamming, fading and so on.

Frequency Hopping with Diversity :-

→ During each 20 ms symbol interval, there are now four columns to the 4 seperate chips to be transmitted for each symbol.

→ Each symbol is transmitted 4 times, & for each transmission the centre freq. of data band is hopped.

→ ie, Each chip interval T_c is

$$T_c = \frac{T}{N} = \frac{20\,ms}{4} = 5\,ms$$

and hopping rate is,

$$\frac{NR}{\log_2 8} = 200\ hops/s.$$

Fast Hopping Vs Slow Hopping :-

→ Frequency Hopping Systems are classified as
(i) Slow frequency hopping (SFH)
(ii) fast frequency hopping (FFH)

→ Slow-frequency hopping (SFH) means there are several modulation symbols per hop.

→ fast-frequency hopping (FFH) means there are several frequency hops per modulation symbol.

→ For SFH, the shortest uninterrupted waveform in the system is that of data symbol, whereas for FFH, the shortest uninterrupted waveform is that of hop.

FFH/MFSK Demodulator :-

→ After filtering with a LPF that has a BW equal to the data BW, the s/l is demodulated using a bank of M envelope or energy detectors.

→ Each envelope detector is followed by a clipping circuit and an accumulator.

→ The demodulator does not make symbol decisions on the chip-by-chip basis.

Processing Gain :-

→ General expression for processing gain as

$$G_P = \frac{W_{ss}}{R}.$$

→ In direct - sequence spread - spectrum, W_{ss} set equal to the chip rate R_{ch}.

→ The gain for frequency hopping systems is written as,

$$G_P = \frac{W_{hopping}}{R}$$

Where, $W_{hopping}$ - Hopping band.

SYNCHRONIZATION

→ For both DS and FH spread - spectrum systems, a Rx must employ a synchronization to demodulate the received s/g successfully.

→ The process of synchronizing with the received spread - spectrum is accomplished in 2 steps, namely, (i) Acquisition

(ii) Tracking

Acquisition :-

→ The acquisition problem is one of searching throughout a region of time & frequency uncertainty in order to synchronize the received spread-spectrum s/l with locally generated spreading s/l.

→ Aquisition scheme can be classified as coherent or non-coherent.

Correlator structures :-

A common feature of all acquisition methods is that ~~the~~ correlating the received s/l & the locally generated s/l to measure the similarity betn them.

Consider the direct-sequence parallel-search acquisition system.

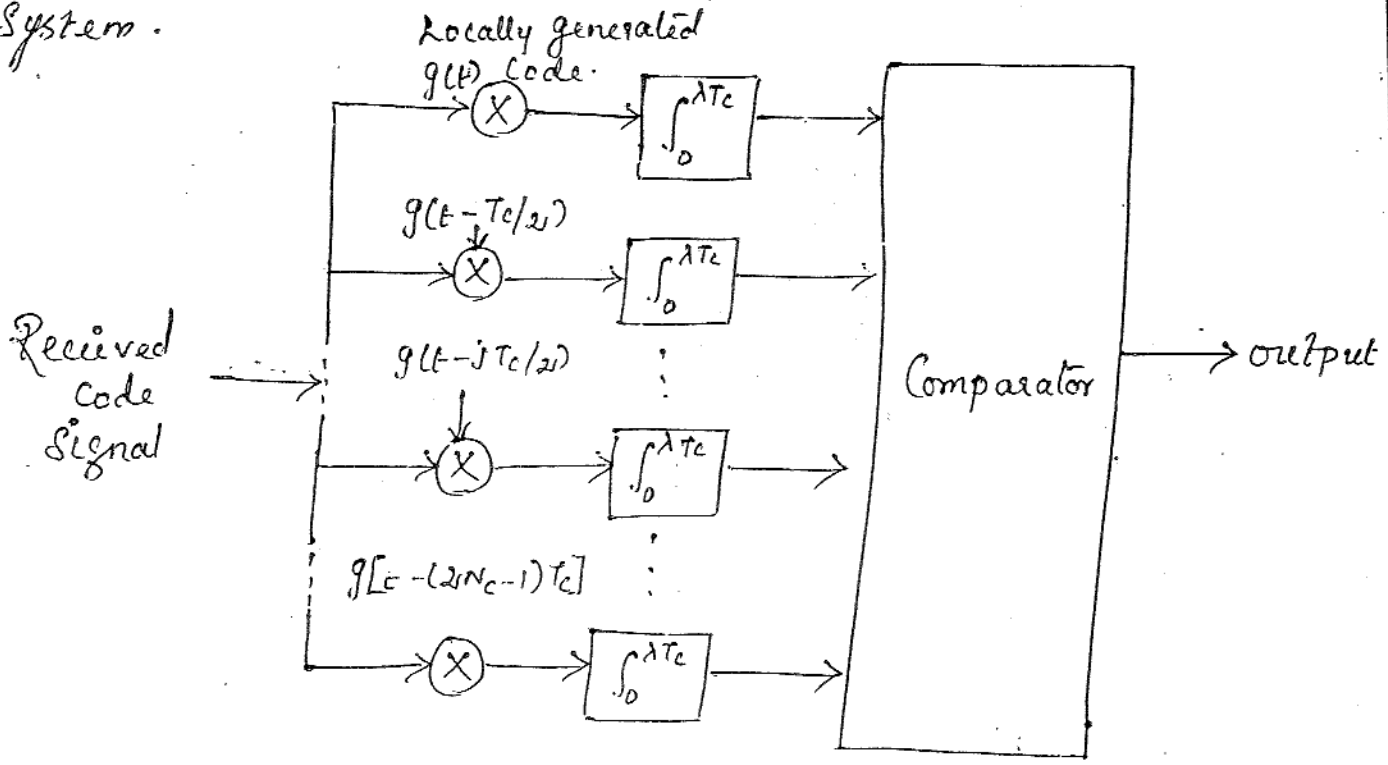


FIG :- Direct Sequence Parallel Search acquisition.

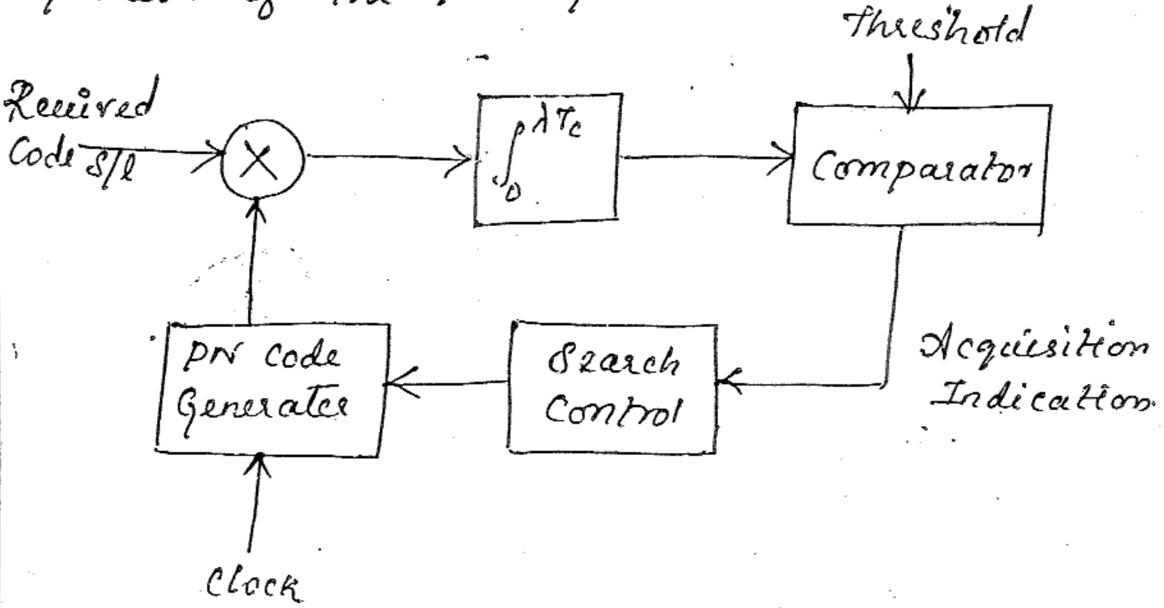
→ This is the simplest of the search techniques

→ It considers all possible code positions in parallel & uses a maximum likelihood algorithm, for acquiring a code.

→ As λ increases, the synchronization error probability decreases.

Serial Search :-

A popular strategy for the acquisition of spread-spectrum s/l is to use a single correlator or matched filter to serially search for the correct phase of the DS code s/l or the correct hopping pattern of the FH s/l.



→ At a fixed estimation of intervals of λT_c, the o/p s/l is compared to present threshold.

→ If the o/p is below the threshold, the phase of the locally generated code s/l is examined.

→ When the threshold exceeded, the PN code is acquired and the code tracking procedure will be intiated.

→ The max. time reqd. for a fully serial DS search is,

$$(T_{acq})_{max} = 2 N_c \lambda T_c.$$

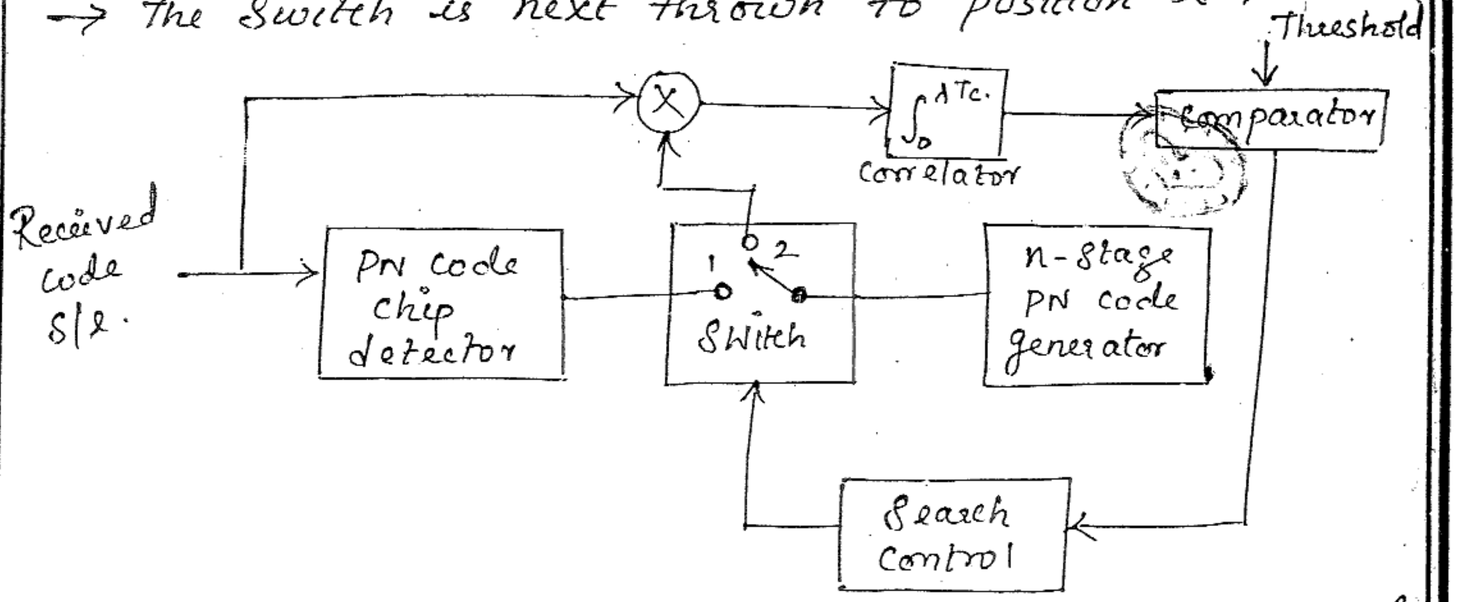
Sequential Estimation :-

→ In this system, the switch is initially at position 1.

→ The RASE S/S enters its best estimate of the first 'n' received code chips into n stages of local PN generator.

→ Therefore, if the first n received chips are correctly estimated, all the following chips will be correctly generated.

→ The switch is next thrown to position 2.



→ If the correlator o/p after λT_c exceeds the threshold level, then the synchronization has occurred.

→ If the o/p is less than the threshold, the switch is returned to position 1.

→ The max. acquisition time when there is noise is present is given by,

$$T_{acq} = nT_c .$$

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