Performance Improvement of GNSS Receiver by Mitigation of Multipath Effects

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Abstract: The Rake Receiver is excessively used in modern CDMA communication but for navigation application it is not self-sufficient to provide satisfactory performance. To overcome the shortcomings of Rake Receiver for navigation purpose one needs to introduce some differential rake architecture which will mitigate the multipath corresponding to the incoming data after it has been processed and demodulated. In this manner a particular will be able to cancel out the multipath and at the end will have only the strongest multipath from which decision can be made to recover the data back.

The other very critical module is Delay Locked Loop (DLL) which will align the code at the receiver end so as to minimize the pseudo range error. The DLL will try to lock the incoming signal with the local code and in order to do so it will consider 3 different locally generated codes Early, Prompt and Late. According to the parameter defined, it may accuracy up to one tenth of a chip. The DLL will use the code-phase provided by the previous blocks and try to find the local code which will give us the minimum pseudo range error.

If the multipath signals are delayed by more than 1.5 chips then matched filter algorithm will detect all three signals by processing on auto-correlation function. But when delay is less than 1.5 chips then NLMS algorithm is used for multipath detection. This two algorithm is incorporated in this design. Whenever incoming signal is received it will first try to find out multipath components within 1.5 chips. After that it will go to the next step in order to find multipath components outside 1.5 chips.

In this project the above mentioned approaches are combined so as to get a system which will give the optimum performance in terms of the SNR and the pseudo range.

Key words: Global Navigation Satellite System (GNSS) Receiver, Modified Rake Receiver, Multipath Overview, Tracking error, Delay Locked Loop, Rake Receiver, Matched Filter Detection, NLMS Algorithm.

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I. INTRODUCTION

Multipath is one of the major error sources in satellite based navigation systems. Most of the satellite based navigation system works on the DS-CDMA techniques in L-band spectrum. The position of user is estimated based on the principle of Triangulation. Various position error occur in this techniques such as Dilution of Precision (DOP), Satellite and Clock error, Ephemeris error, Ionospheric error, Tropospheric error and Multipath error. All these errors have been discussed briefly. There are two major errors: Ionospheric and Multipath errors. Normally Ionospheric errors can be mitigated using Dual frequency transmission or using a suitable algorithm. Multipath error can be mitigated using various techniques such as Multipath Estimating Delay Lock Loop (MEDLL), Modified RAKE Delay Lock Loop (MRDLL), Multipath Mitigation Technology (MMT), Narrow Correlator, Double Delta technique Vision Correlator (VC), TurboDLL and others. These techniques have been discussed in detail in this paper. The technique using the Rake receiver is generally used in Communication System. It is envisaged that this technique to mitigate the multipath error significantly.

The Rake based architecture for multipath estimation and mitigation technique employs a novel form of multipath estimation and mitigation technique in which several architectures are combined to enhance performance of the GNSS Receivers.

This project aims at simulating various modified architecture and understanding the procedure to improve the SNR and the pseudo range for a system.

The Rake Receiver is excessively used in modern CDMA communication but for navigation application it is not self-sufficient to provide satisfactory performance. To overcome the shortcomings of Rake Receiver for navigation purpose one needs to introduce some differential rake architecture which will mitigate the multipath corresponding to the incoming data after it has been processed and demodulated. In this manner a particular will be able to cancel out the multipath and at the end will have only the strongest

multipath from which decision can be made to recover the data back.

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But when delay is less than 1.5 chips then NLMS algorithm is used for multipath detection. This two algorithm is incorporated in this design.

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In this project the above mentioned approaches are combined so as to get a system which will give the optimum performance in terms of the SNR and the pseudo range.

II.   Multipath Overview

Due to reflections from obstacles a radio channel can consist of many copies of originally transmitted signals having – different amplitudes, phases, and delays. This is called Multipath components. Multipath is the reception of reflected or diffracted replicas of the desired signal. Since the path travelled by a reflection is always longer than the direct path, multipatharrivals are delayed relative to the direct path. When the multipath delay is large, a receivercan readily resolve the multipath. As long as the receiver tracks the direct path (which always arrives earlier than any multipath), such resolvable multipath have little effect on performance.
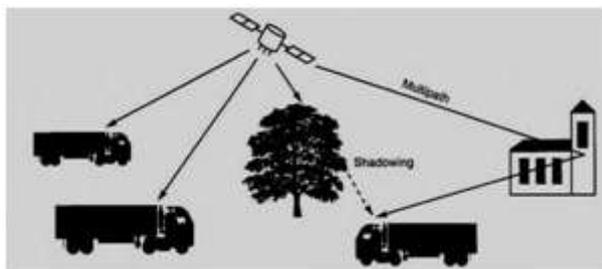

Fig.1 Outdoor multipath situations

Typically, consideration of multipath in a GNSS context emphasizes its effect onsignal code and carrier tracking accuracies, since these receiver functions are more sensitive to multipath degradation than signal acquisition or data

demodulation under most situations, multipath conditions that would cause observable degradation to acquisition or data demodulation also introduce large degradations to pseudo range accuracy.

III.   Introduction to Rake Receiver

A **Rake Receiver** is a radio receiver designed to counter the effects of multipath fading. It does this by using several "sub-receivers" called *fingers*, that is, several correlators each assigned to a different multipath component. Each finger independently decodes a single multipath component; at a later stage the contribution of all fingers are combined in order to make the most use of the different transmission characteristics of each transmission path. This could very well result in higher signal-to-noise ratio (or Eb/N0) in a multipathenvironment than in a "clean" environment.

Rake Receiver found it's application in communication & GNSS Receiver. In communication the only important aspect is Data demodulation, while in GNSS Receiver pseudo range calculation is also critical aspect along with Data demodulation.

IV.   Conventional Rake Receiver

A RAKE receiver utilizes multiple correlators to separately detect M strongest multipath components. The outputs of each correlator are weighted to provide better estimate of the transmitted signal than is provided by a single component. Demodulation and bit decisions are then based on the weighted outputs of the M correlators.
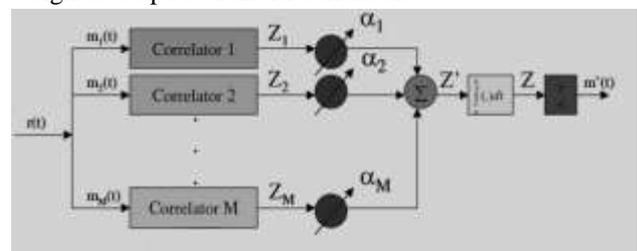

Fig2. Conventional Rake Receiver

Each correlator detects a time-shifted version of the original CDMA transmission, and each finger of the RAKE correlates to a portion of the signal, which is delayed by at least one chip in time from the other fingers. Assume M correlators are used in a CDMA receiver to capture M strongest multipath components. A weighting network is used to provide a linear combination of the correlator output for bit decision. Correlator 1 is synchronized to the strongest multipath m1. Multipath component m2 arrived t1 later than m1 but has low correlation with m1. The M decision statistics are weighted to form an overall decisionstatistic as shown in Fig2. The outputs of the M correlators are denoted as Z1, Z2,…, and

ZM. They are weighted by α1, α2,…, and αM, respectively. The weighting coefficients are

based on the power or the SNR (Signal-to-Noise Ratio) from each correlator output. If maximal-ratio combining is used, following equation can be written for Z'.

$$Z' = \sum_{m=1}^{M} \alpha_m Z_m$$

The weighting coefficients, αm, are normalized to the output signal power of the correlator in such a way that the coefficients sum to unity, as shown in following equation.

$$\alpha_m = \frac{Z_m^2}{\sum_{m=1}^{M} Z_m^2}$$

V.   Use of Rake Receiver in GNSS

From the above written literature, one thing is clear that Rake receiver is used to compensate the multipath fading effect of the channel. In GNSS the transmitted signals are also affected by this fading effect. Hence this method is very useful in GNSS.
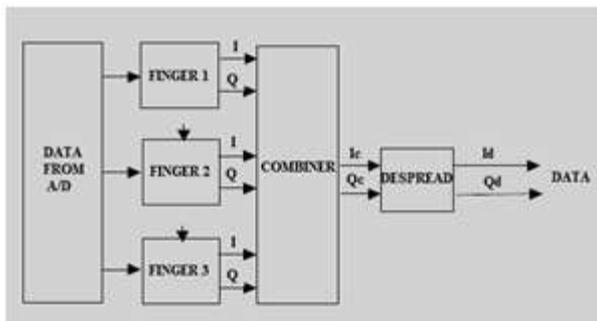
Fig3. Rake Receiver in GNSS

In GNSS first of all every multi-paths are passed through demodulation block, where the signals are down converted to 20.46 MHz Then they are detected in different-different fingers according to their phase offset from the original phase. This offset is called codephase, which is obtained by the Matched Filter.

After detection they are weighted with different different factors in order to compensate the amplitude fading. This technique is called Maximal Ratio Combining (MRC). Then after this all fingers outputs are added together to get the estimated output of the original signal. After detecting the original signal it is despreaded using locally generated code. There are two possibilities while dealing with multipath environment depending on the relative phase delay between two multipath components. The first possibility can be termed as, when the delay between multipath components is less than 1.5 chips and other possibility is the delay being more than 1.5 chips.Each of these issues can be dealt using different algorithm at multipath estimation stage. For the delay between the multipath being greater than 1.5 chips we use the matched filter algorithm to find out the amount of delay and for the delay being less than 1.5 chips we use the NLMS (Normalized Least Mean Square) algorithm.

VI.   Introduction to Matched Filter

A matched filter is a filter whose frequency response is designed to exactly match the frequency spectrum of the input signal.
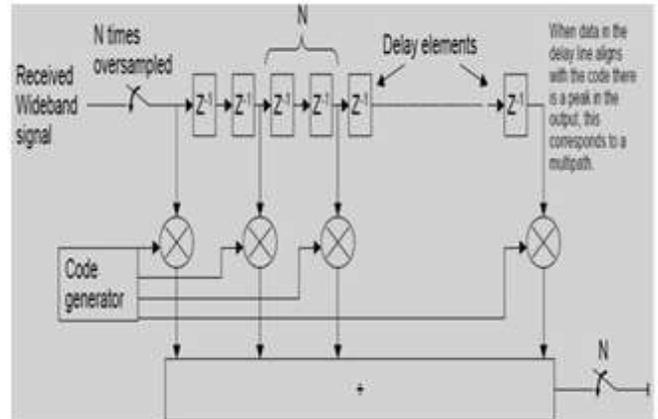

Fig4. Matched filter block diagram

VII.   Matched-Filter Detection

A matched filter is a linear filter designed to maximize the output signal-to-noise ratio for a given input signal. Suppose that a signal *s* (*t*) plus additive white Gaussian noise *n* (*t*) is input to a linear time-invariant filter followed by a sampler. Let *S* (*f*) be the Fourier transform of s(*t*). Parseval's theorem states that the average signal energy is

$$\mathbf{E} = \int_{-\infty}^{+\infty} s(t)^2 \, dt = \int_{-\infty}^{+\infty} |S(f)^2| \, df$$

The signal at the output of the filter is

$$s_0(t) = \int_{-\infty}^{+\infty} S(f)H(f)e^{j2\pi ft} \, df$$

At time $t = t_0$, we let

$$A = |s_0(t)| = \left| \int_{-\infty}^{+\infty} S(f)H(f)e^{j2\pi ft_0} \, df \right|$$

Since the input noise power spectral density is given by

$$G_n(\mathrm{f}) = {n_0}/{2}$$

the noise power spectral density at the output of the filter is

$$G_{n_0}(f) = G_n(f) \, |H(f)|^2 = \frac{n_0}{2} |H(f)|^2$$

and the average output noise power is

$$N = \int_{-\infty}^{+\infty} G_{n_0}(f) \, df = \frac{n_0}{2} \int_{-\infty}^{+\infty} |H(f)|^2 \, df$$

At time $t = t_0$, we have

$$\frac{A^2}{EN} = \frac{\left| \int_{-\infty}^{+\infty} S(f)H(f)e^{j2\pi ft_0} \, df \right|^2}{\int_{-\infty}^{+\infty} |S(f)^2| \, df \frac{n_0}{2} \int_{-\infty}^{+\infty} |H(f)|^2 \, df}$$

Schwarz's inequality states that, given arbitrary complex functions *X*(*f*) and *Y*(*f*) of a dummy variable *f*, then

$$\left| \int_{-\infty}^{+\infty} X(f)Y(f)df \right|^2 \leq \left| \int_{-\infty}^{+\infty} X(f) \right|^2 df \left| \int_{-\infty}^{+\infty} Y(f) \right|^2 df$$

Equality holds when $Y(f) = K \, X*(f)$, where *K* is a constant and *X**(*f*) is the complex conjugate of *X*(*f*). We can apply Schwarz's inequality in our matched-filter case by letting

$X(f) = S(f) \, e^{j2\pi ft_0}$ and $Y = H(f)$

When equation may be written as

$$\left|\int_{-\infty}^{+\infty} S(f)e^{j2\pi f t_0}H(f)df\right|^2 \leq$$

$$\left|\int_{-\infty}^{+\infty} S(f)\right|^2 df \ \left|\int_{-\infty}^{+\infty} H(f)\right|^2 df$$

Equality holds when

$$H(f) = K[S(f)e^{j2\pi f t_0}]^*$$

Therefore

$$H(f) = KS^*(f)e^{-j2\pi f t_0}$$

And equation becomes

$$\frac{A^2}{EN} = \frac{2}{n_0}$$

$$\sqrt{\frac{2E}{n_0}} = \frac{A}{\sqrt{N}}$$

Equality yields maximum output signal-to-noise ratio(SNR). Taking the inverse Fourier transform of $H(f)$ in equation, we get

$$h(t) = \int_{-\infty}^{+\infty} K\,S*(f)e^{j2\pi f(t-t_0)}\ df$$

For real $h(t)$, $S(f) = S^*(f)$. Thus

$$h(t) = \int_{-\infty}^{+\infty} K\,S(f)e^{j2\pi f(t_0-t)}df$$

$$h(t) = K\,S(t_0\text{-}t)$$

The impulse response of the matched filter is a delayed version of the mirror image of $s(t)$.

NLMS Algorithm

The task of multipath estimator is to estimate the multipath delay profile by the use of adaptive filter. There are many algorithms that could be used in this context; most are variations of the least mean squared (LMS) algorithm. Some variations include normalized

LMS (NLMS) and the recursive least squares algorithm (RLS). The NLMS algorithm was chosen because it is the most commonly used algorithm in adaptive filtering applications, it is powerful enough to accomplish the system's requirements and is also relatively simple compared to the other algorithms.
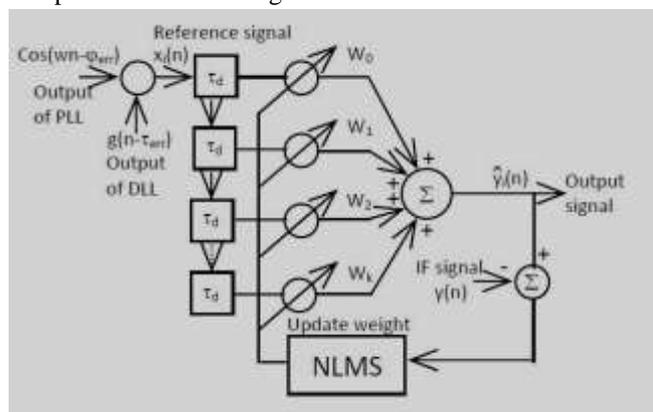
Fig5. NLMS Algorithm

In the presence of multipath, digital IF signal, i.e. output signal at the A/D converter can be written as:

$$\hat{y}(n) = \sum_{i=0}^{\hat{M}} \hat{A}_i\, g(n - \hat{\tau}_i)\cos(wn + \hat{\varphi}_i) + \eta(n)$$

Where A, τ and ϕ are the amplitude, the code delay, and the carrier phase of mth delayed signal. M is the number of multipath component, g is spread-spectrum code, and ω is IF frequency and n is discrete time. The 0th delayed signal corresponds to the direct signal.

The parameter with the symbol "^" denoted the estimated parameter.

VIII. Limitation of Existing Technologies

From the above discussion it is clear that minimum multipath resolvable capability of Matched Filter is 1 chip. Hence it cannot resolve the multi-paths whose relative delays are less than one chip period. While NLMS Algorithm will solve this difficulty, but at the cost of increment in Hardware, when the relative delay between multipath components are greater than one chip period. Hence one must have to design optimize solution for both this scenarios. The best possible optimization is provided in design. This will work for both the cases.

IX. Introduction to Modified Approach

As we have seen in the previous section, the main objective of the GNSS Receiver is the SNR improvement along with better pseudo range measurement. For that some modification is required in the existing Rake The basic modification is listed below:

Gold Sequence Generation—Overview

The generation of the Gold codes is sketched in Figure. The C/A code generator contains two shift registers known as $G1$ and $G2$. These shift registers each have 10 cells generating sequences of length 1023. The two resulting 1023 chip long sequences are modulo-2 added to generate a 1023 chip-long C/A code, only if the polynomial is able to generate code of maximum length. Every 1023rd period, the shift registers are reset with all ones, making the code start over. The $G1$ register always has a feedback configuration with

$$f(x) = 1 + x^3 + x^{10},$$

meaning that state 3 and state 10 are fed back to the input. In the same way, the $G2$ register has the polynomial

$$f(x) = 1 + x^2 + x^3 + x^6 + x^8 + x^9 + x^{10}.$$

To make different C/A codes for the satellites, the output of the two shift registers are combined in a very special manner.

The $G1$ register always supplies its output, but the $G2$ register supplies two of its states to a modulo-2 adder to generate its output. The selection of states for the modulo-2 adder is called the phase selection.
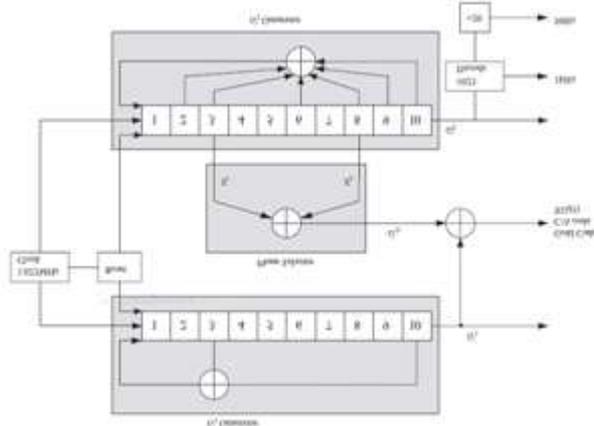
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Fig6. Gold Code Generation

$G1(x) = 1 + x^3 + x^{10}$

$G2(x) = 1 + x^2 + x^3 + x^6 + x^8 + x^9 + x^{10}$

Correlation Properties

The Gold codes are selected as spreading sequences for the GPS signals because of their characteristics. The most important characteristics of the C/A codes are their correlation properties. These properties are described now. The two important correlation properties of the C/A codes can be stated as follows:That is, for two codes *Ci* and *Ck* for satellites *i* and *k*, the cross correlation can be written as

$$r_{ik}(m) = \sum C_i(l)Ck(l+m) \approx 0 \text{ for all } m$$

Nearly no correlation except for zero lags All C/A are nearly uncorrelated with themselves, except for zero lag. This property makes it easy to find out when two similar codes are perfectly aligned. The autocorrelation property for satellite *k* can be written as

$$r_{kk}(m) = \sum C_k(l)Ck(l+m) \approx 0 \text{ for } |m| \geq 1$$

Fig7 shows an example of the auto- and cross-correlation properties of the C/A code.
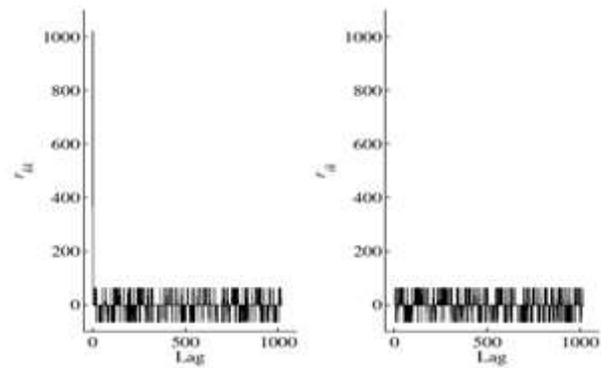
Fig7. Correlation properties of the C/A codes. Left: Autocorrelation *rkk (n)* of the C/A code for PRN 1. Right: Cross correlation *rik (n)* of the C/A codes for PRNs 1 and 2.

Acquisition

The purpose of acquisition is to determine visible satellites and coarse values of carrier frequencyand code phaseof the satellite signals. The satellites are differentiated by the 32 different PRN sequences. Basically there are two methods for Acquisition:

1. Serial search Acquisition
2. Parallel code phase search Acquisition

i)   Serial Search Acquisition

Serial search acquisition is an often-used method for acquisition in code-division multiple access systems (CDMA). GPS is a CDMA system. Fig8. is a block diagram of the serial search algorithm.
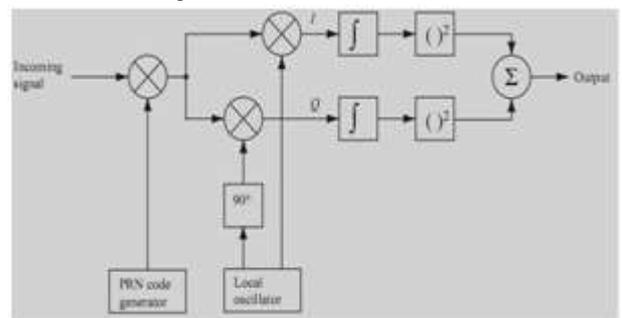
Fig8. Serial Search Acquisitions

ii) Parallel Code Phase Search Acquisition

As the name parallel code phase search acquisitionimplies, this second method of acquisition parallelizes the search for the one parameter. This method utilizes the Fourier transform to perform a transformation from the time domain into the frequency domain Fig9. is a block diagram of the parallel code phase search algorithm.

The incoming signal is multiplied by a locally generated PRN sequence, with a code corresponding to a specific satellite and a code phase between 0 and 1022 chips. The resulting signal is transformed into the frequency domain by a Fourier transform. The Fourier transform could be implemented as a discrete Fourier transform (DFT) or a fast

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Fourier transform (FFT). The FFT is the faster of the two; but it requires an input sequence with a radix-2 length, that is, $2n$, where n takes positive integer value.
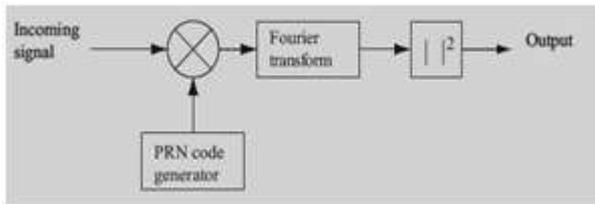
Fig9. Parallel Code Phase Search Acquisitions

Code Tracking

Due to relative motion between satellite and earth-receiver, the phenomena called DopplerShift always exist, in which the carrier frequency of the transmitted signal is changed.

Because of change in carrier frequency the data cannot be extracted from carrier at receiver side. Hence compensation for this Doppler Effect is required. For this purpose DLL (Delay Locked Loop) system is implemented in GNSS receiver.

Delay Locked Loop

The code tracking loop in the GPS receiver is a delay lock loop(DLL) called an early– late tracking loop. The idea behind the DLL is to correlate the input signal with three replicas of the code seen in Fig10.
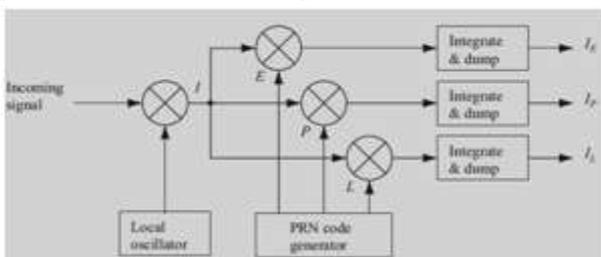
Fig10. Basic code tracking loop block diagram

Suppose we take 5 samples per chip & suddenly it loses the phase of one tap. It will look like as shown below:
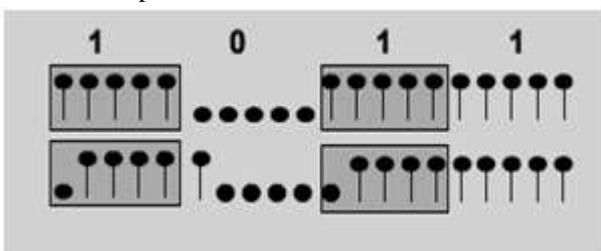
Fig11. Received C/A code and replica code out of phase`

This will cause the correlation to drop, but this information alone is not enough to compensate for the phase shift that occurred.. Even if we knew that the correlation drop was only because of a phase shift we would not know whether to shift the PRN code left or right.
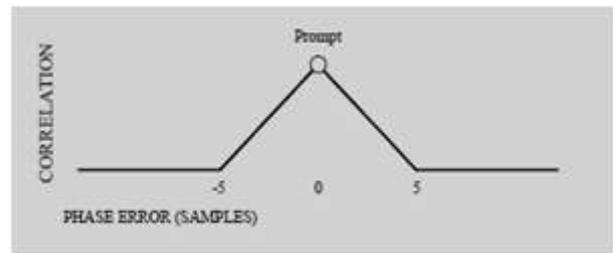
Fig12. Prompt Replica Code Correlation Plot

As we can see in the fig12.above, the correlation ideally slides down linearly from maximum correlation to zero correlation at five samples that is when the phase error is one full chip. If the phase error becomes one full chip there should not be any correlation since the PRN code is supposed to act like white noise which is uncorrelated. So if a shift occurs the mark will slide to the right or left, depending on the nature of the shift.

In order to be able to determine the direction of the slide we introduce two additional PRN codes according to the new PRN codes are called early and late, the original PRN code is from now on called prompt and is the one we will try to keep phase aligned. The early PRN code is the prompt PRN code shifted 3 samples to the right and the late PRN code is shifted 3 samples to the left. This gives us a correlation/phase-error plot like in fig12.
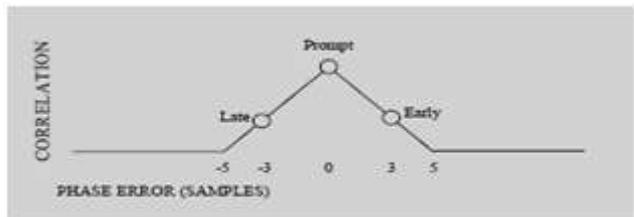
Fig13. Prompt/Early/Late Replica Code Correlation Plot

The discriminator algorithm is to give a calculated number on the phase error that is present in the receiver that is implemented. The discriminator output signal, E, is calculated;

$$E= \frac{early}{late}$$

This discriminator will give us

E = 1, when we are perfectly aligned,

E > 1, if we should shift the code to the right,

E < 1, if we should shift the code to the left.

The discriminator used in our design is I_E - I_L. Where I_E and I_L are the auto-correlation value of incoming signal with early and late code.

Adaptive Path Estimator

The use of differential techniques theoretically eliminates all error sources which are common to both receivers. The error which remains is multipath, and it becomes the dominant error source in high precision GPS applications. Multipath errors are not identical to the GPS reference station and remote receivers. Thus, it becomes the significant error

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source in differential GPS. In this paper, a multipath mitigation tracking system is presented for static GPS applications.
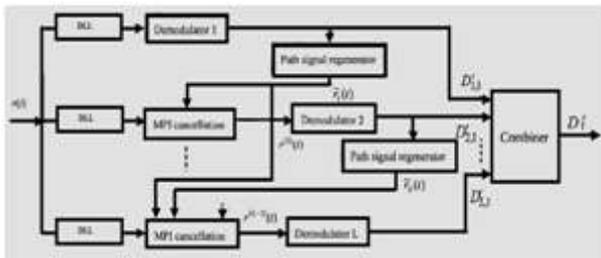

Fig14. General concept of Modified Architecture

In this technique each multipath is cancelled from the original signal after it has been estimated.

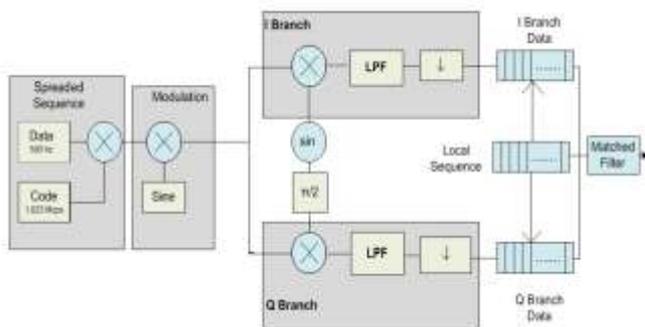### X. MATLAB Designs & Simulation Results

a) MATLAB Implementation

Fig15. Pre-processing simulation

In Matlab Rake receiver can be implemented by .m file or by simulink, but Simulink will take longer time for execution, so we have implemented it using .m file. We have taken here a data of 500 Hz (period=2 ms) for 5 ms duration. This data is first spreaded by goldcode of 1.023 MCPS. Then this spreaded sequence is modulated using carrier signal. This carrier signal is of frequency 20.46 MHz. Then these modulated signals are transmitted.Because of Multipath effects this signals are not received at the same time, but they are arriving at receiver base station at different-different time, with different-different amplitudes. In our simulation we have generated this Multipath effect by giving delays to the original signals & also different amplitudes are provided by multiplying them with different factors.

Here are some specifications which were used in the MATLAB Simulation,

Design Specifications

PARAMETERS	
IF A/D Sampling Rate	20.46 MHz
IF Central Frequency	4.092 MHz
Modulation	BPSK
Spreading	DSSS

Technique	
Spreading code	Gold Code(C/A Code)
Data Rate	50 bps
Chip Rate	1.023 MCPS
Resolution	20 samples per chip
Minimum SNR	-33 dB
Acquisition Duration	1023 ms

Table 1 Design Specification for MATLAB Simulation

b) CbyA Sequence Generations in MATLAB

I started MATLAB Simulation by generating the CbyA Code sequence which is used to despread the data.The generation of the Gold codes is sketched in Figure. The C/A code generator contains two shift registers known as *G*1 and *G*2. These shift registers each have 10 cells generating sequences of length 1023. The two resulting 1023 chip long sequences are modulo-2 added to generate a 1023 chip-long C/A code, only if the polynomial is able to generate code of maximum length. Every 1023rd period, the shift registers are reset with all ones, making the code start over.

The *G*1 register always has a feedback configuration with the polynomial

$$f(x) = 1 + x^3 + x^{10}$$

meaning that state 3 and state 10 are fed back to the input.

In the same way, the *G*2 register has the polynomial

$$f(x) = 1 + x^2 + x^3 + x^6 + x^8 + x^9 + x^{10}.$$
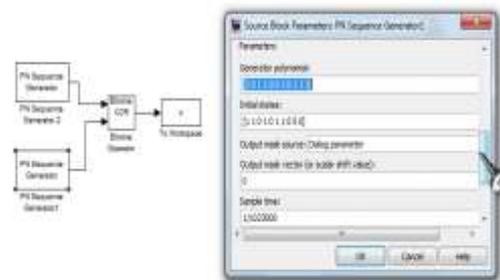
Fig16. Gold sequence Generator polynomial 1
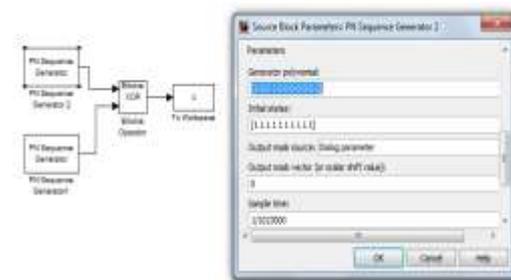
Fig17. Gold sequence generator polynomial 2

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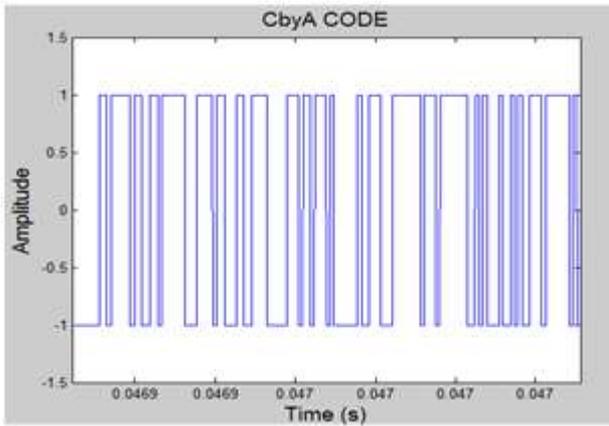
Fig18. CbyA CodeData Generation

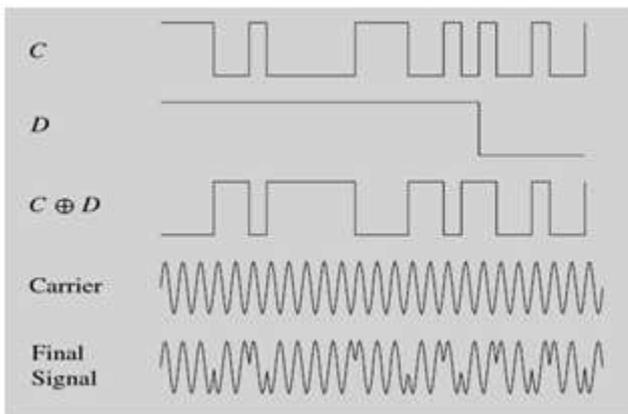**Fig19. NRZ Data(100 Hz)BPSK Modulation**

Fig20. BPSK Modulation

For MATLAB simulation we have considered the NRZ Data (100 Hz) and the CbyA code and since they were both in the NRZ form we just multiplied them instead of modulo-2 addition.
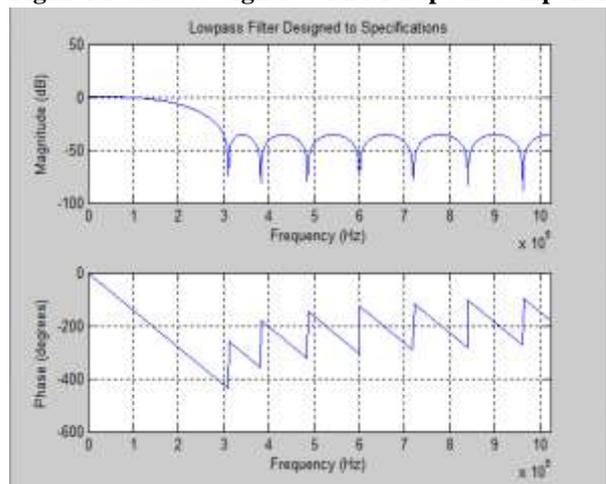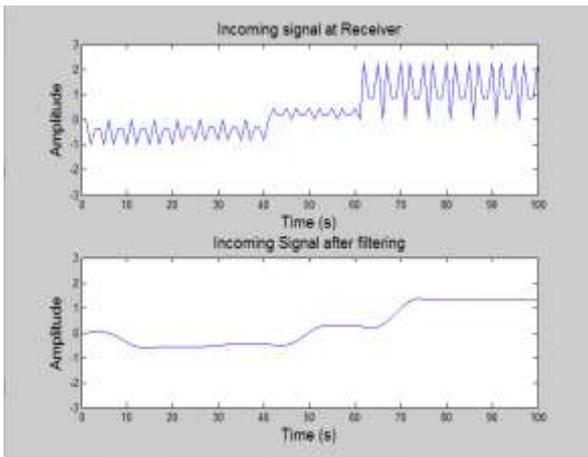

Fig21. BPSK Modulated Signal

Fig22. Modulated Signals with Multipath Components

Fig23. Filter designed to Specifications

Fig24. Effect of Low Pass Filtering on the Incoming signal

Fig25. Output from the Serial/Parallel Code Phase search

Fig26. Actual Weights and Estimated Weights

Fig27. The Estimated code after 1000 iterations

Fig28. The Estimated code after 10000 iterations
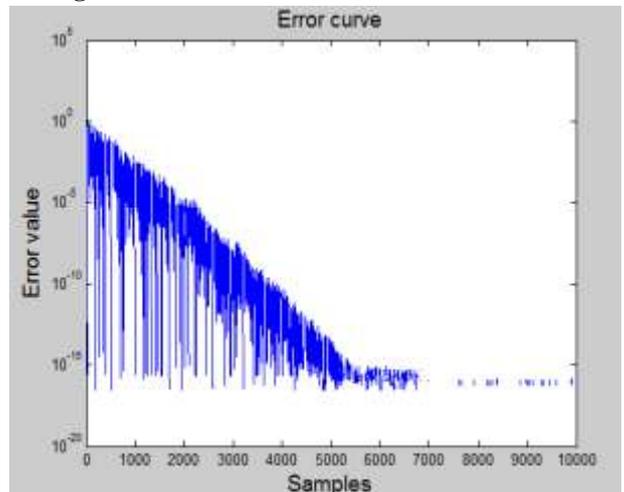
Fig29. Error between the estimated and desired code

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Modified Rake Based Architecture
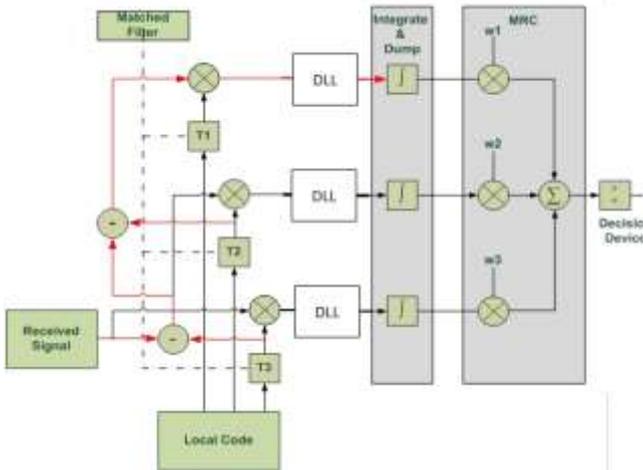
Fig30. Modified Rake Based Architecture
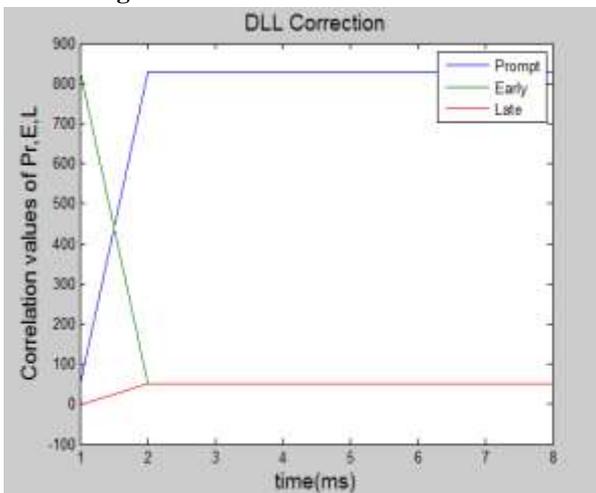
Fig31. The output of the correlation of the prompt, early, late signals
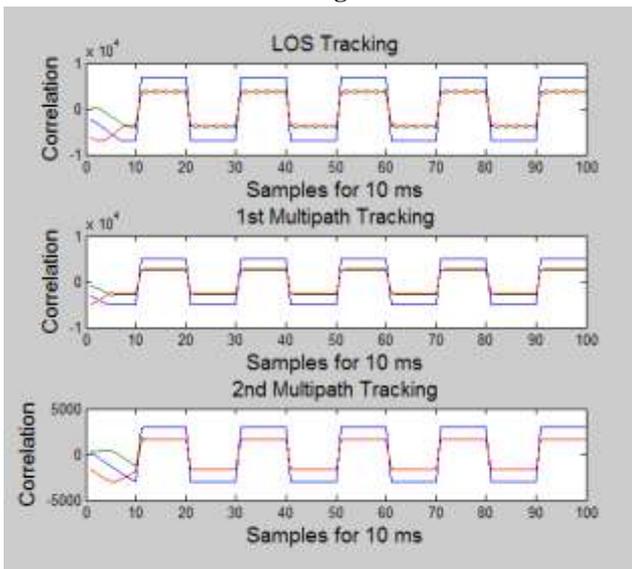
Fig32. Code Tracking for Multipath case
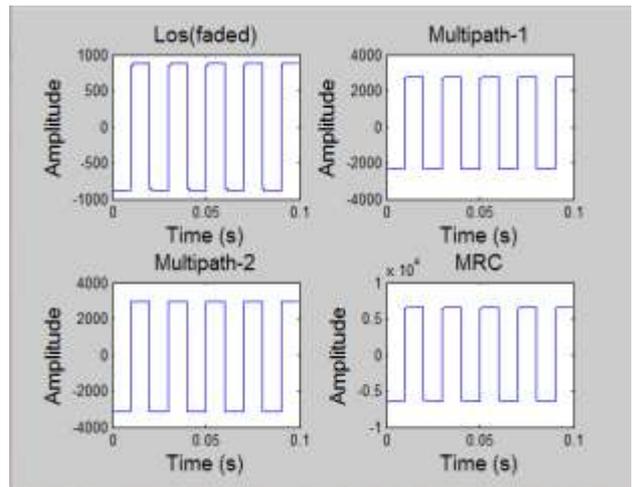
Fig33. The despreded code
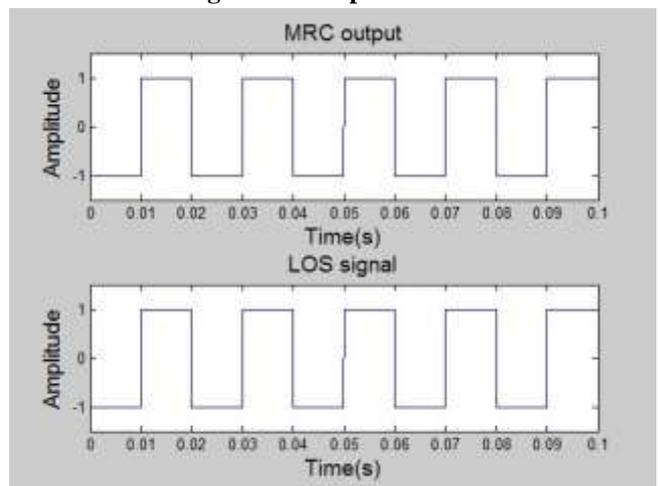
Fig34. The Reconstructed Data

Testing of MATLAB Design
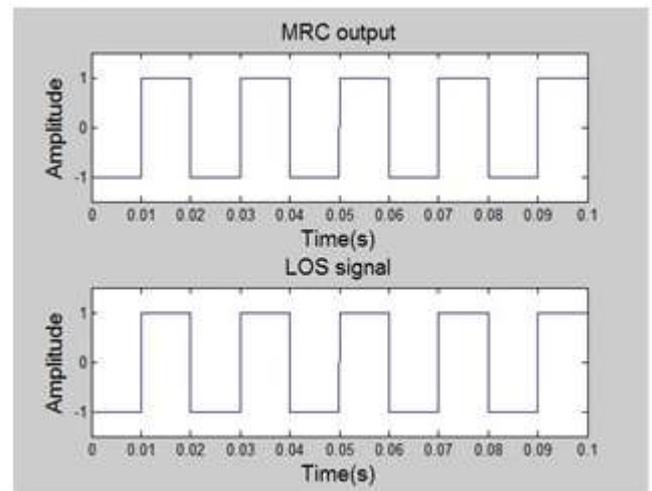
multipath components it will take into consideration only the strongest three components and discard the others.

$$r(t) = \alpha \cdot LOS + \beta \cdot Multipath\ 1 + \gamma \cdot Multipath\ 2$$

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Case	Value of α	Value of β	Value of γ
1	1	0.7	0.4
2	0.5	0.8	0.3

Table 2 Different Cases Considered for testing Purpose

Effect on spectrum due to Multipaths and the Noise

Here we have considered the signal with $\alpha = 1, \beta = 0.7, \gamma = 0.4$ and we have kept the noise floor at -20 db SNR.
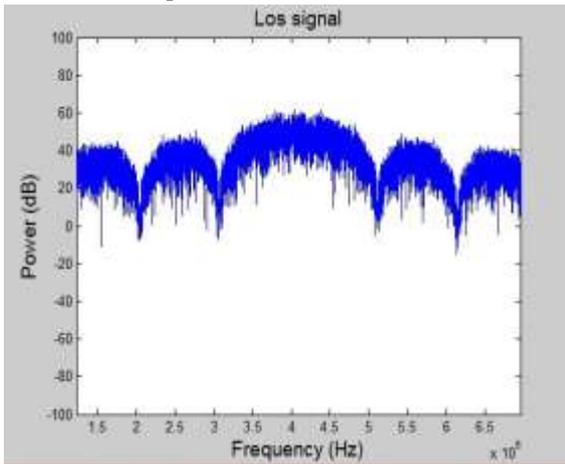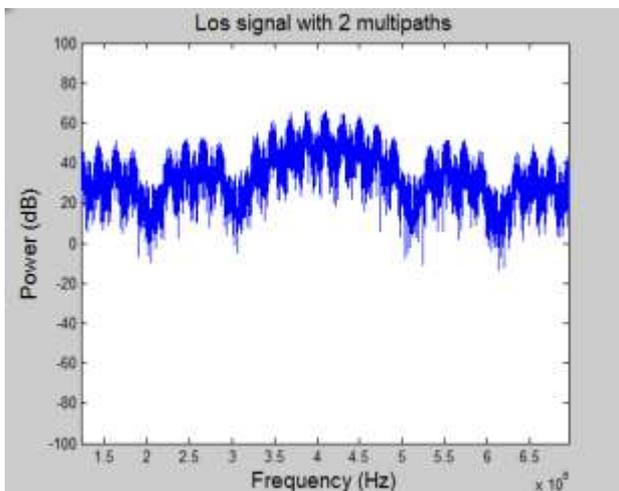

Fig35. Spectrum of LOS Signal
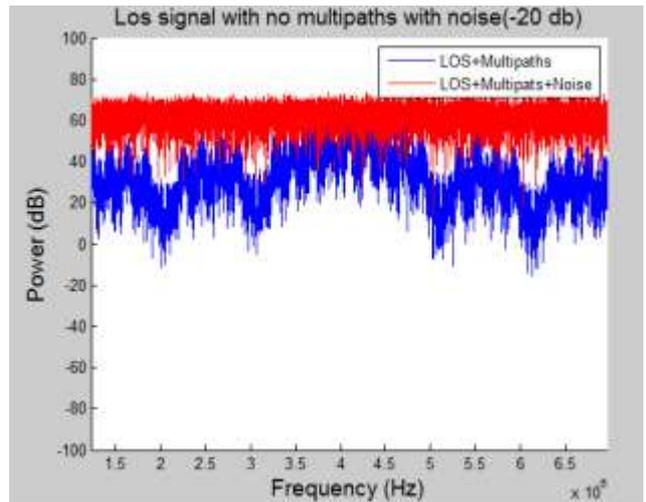

Fig36. Spectrum of LOS Signal with Multipath Components

Fig37. Spectrum of LOS + Multipath With Noise
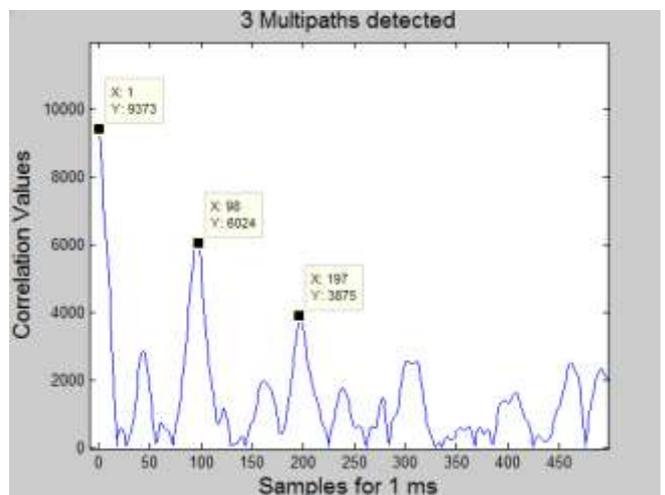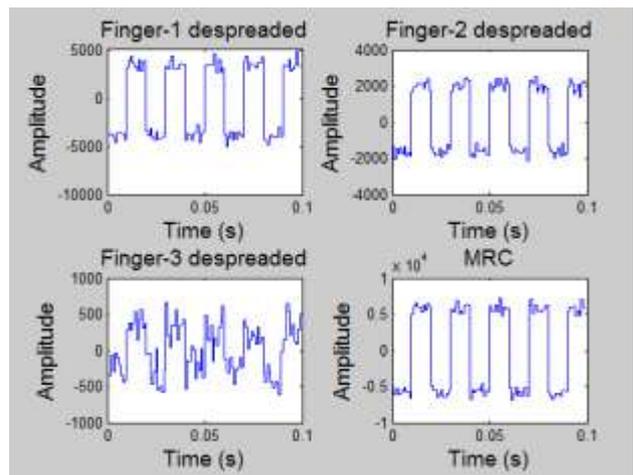

Fig38. Matched Filter input for LOS + Multipath

Fig39. The Despreaded Code for LOS and Multipath components at -20 dB Noise
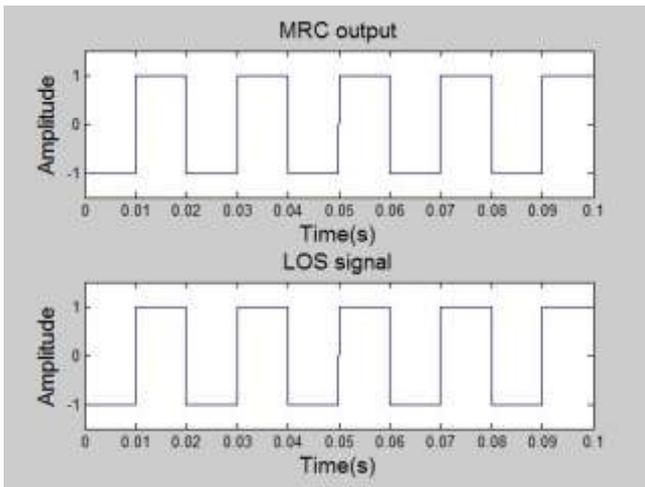
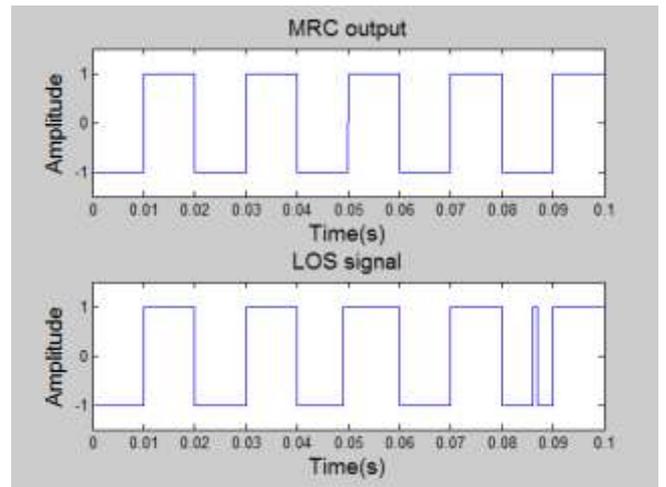**Fig40. The Reconstructed Data**

Fig43. The Reconstructed Data at -28 db Noise
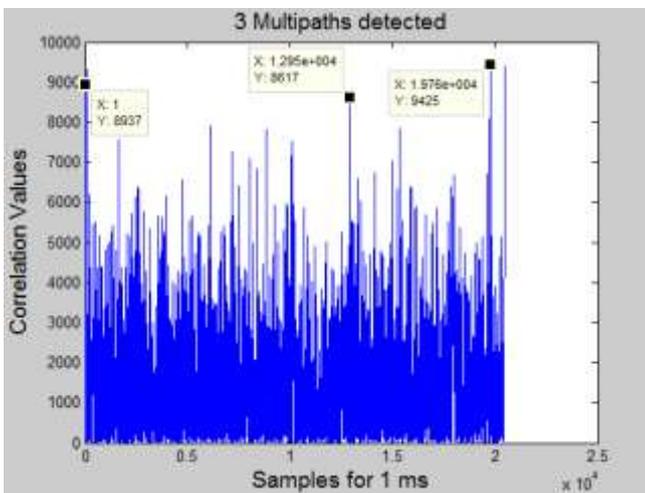

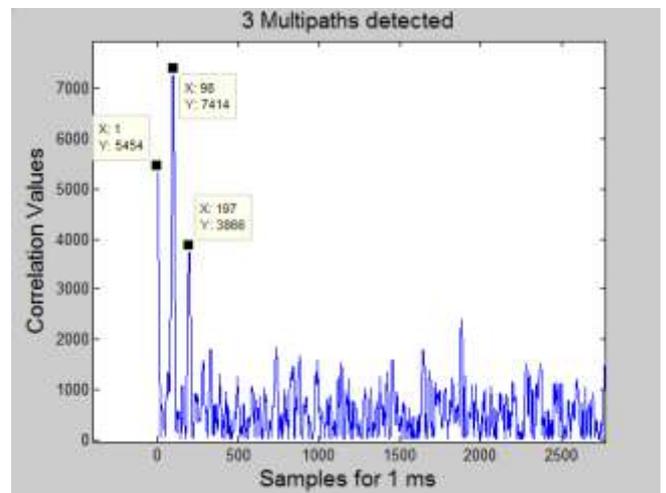**Fig41. The Matched Filter input for LOS + Multipath case at -28 db SNR**

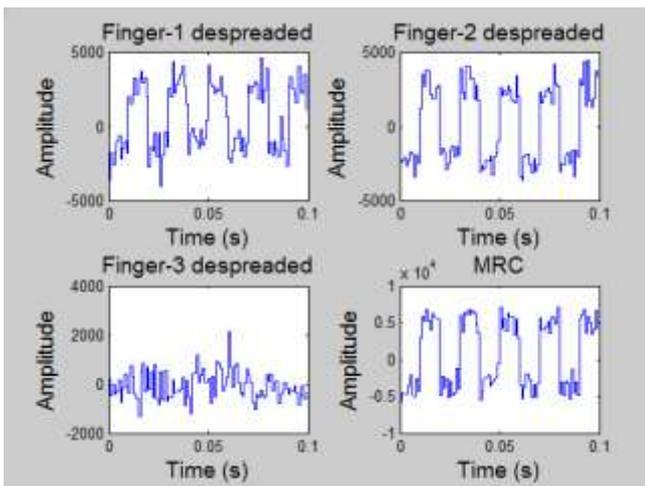**Fig44. Matched Filter input for LOS faded case with moderate noise**

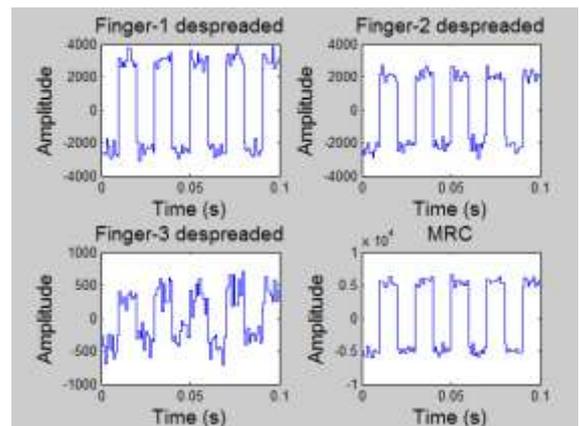**Fig42. The Despreaded Code for LOS + Multipath case at -28 db Noise**
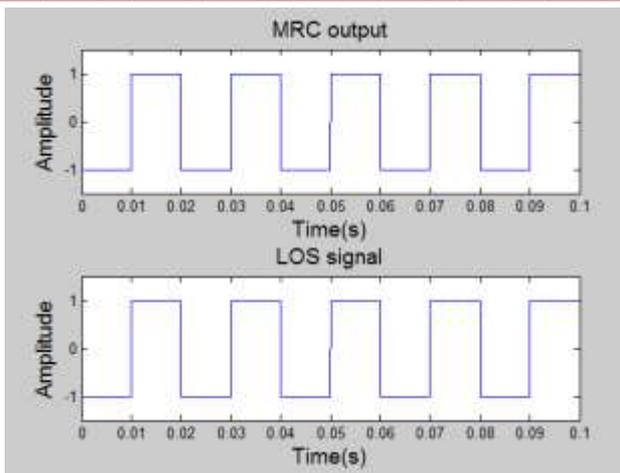

Fig45. The Despreaded Code with LOS faded at moderate noise
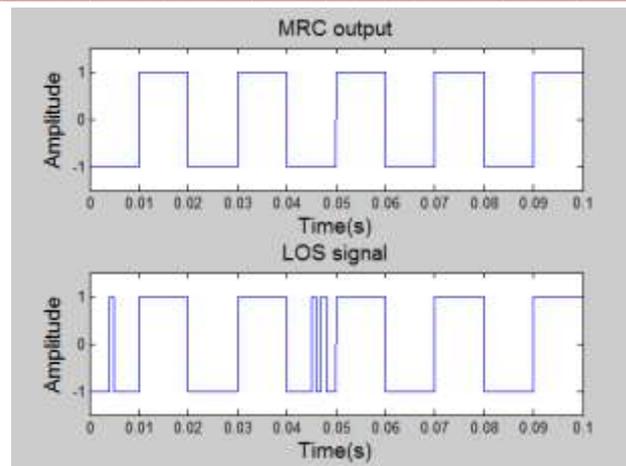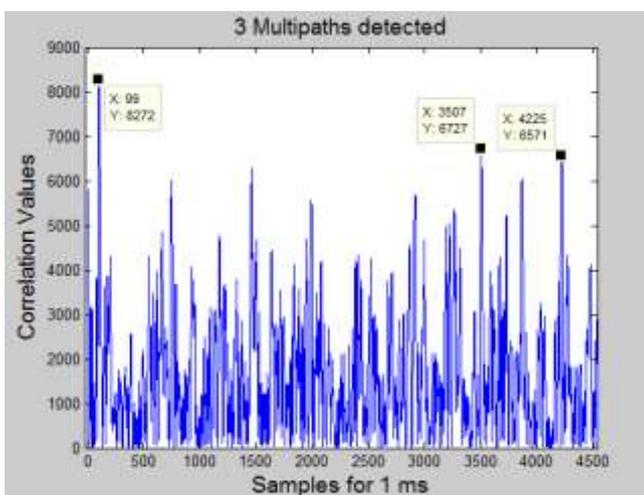
Fig46. The Reconstructed Data

Fig47. The matched filter input with faded LOS at high noise (-28 DB)

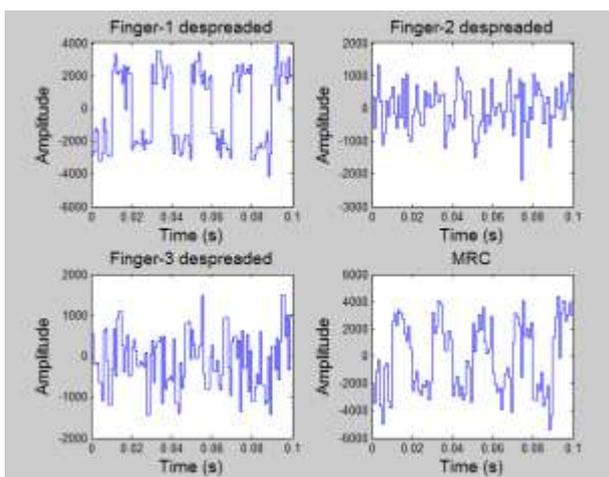**Fig48. The Despreaded code with LOS faded at high noise(-28 dB)**

Fig49. The Reconstructed Data with LOS faded at high noise(-28 dB)

XI. CONCLUSION

The Rake based DLL architecture for multipath estimation and mitigation is simulated in MATLAB for different Multipath profiles. The basic modification in this design as compare to conventional receiver is Serial Multipath Cancellation and Capability ofresolving Multipath components either within or outside 1.5 chips apart. The effect of both these modifications is tested individually.

This design is made up of 3 fingers. So it will detect strongest three signals among which one signal is LOS if it is not faded due to noisy environment. In ideal case, means if we consider that there are no any multipath components present for noiseless environment then this design will recover data up to -33 dB SNR. But for real world environment for -33 dB SNR data cannot be resolvable.

Another critical modification is Multipath Resolvable Capability. In real world environment when signal is transmitted from satellite & received at user receiver it is consist of LOS signal and multipath components delayed by either more than 1.5 chips or within 1.5 chips. So this design can be used in both these scenarios. First this design uses NLMS Algorithm to find out multipath code phase within 1.5 chips. After that it uses Matched Filter Algorithm to find code phase which are more than 1.5 chips. Both these Algorithms are checked individually and together.

Future Extension

This design is used to recover data from the baseband signal. Means in this design it is assumed that the carrier frequency used for BPSK modulation is known at receiver side. But in real world due to relative motion between transmitter & receiver there exist a Doppler shift. Hence at receiver side the exact carrier frequency should be known in order to demodulate the original signal.

For these purpose Phase Locked Loop (PLL) & Frequency Locked Loop (FLL) block is used. These two blocks will be

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incorporated in our design in order to use this design in real world environment.

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