Adaptive Signal Processing techniques

Prof. B S Joshi

Assistant Professor
Electronics and Communication Engineering
Shantilal Shah Engineering College, Bhavnagar, Gujarat, India

***Abstract*: In GPS the satellite signal is easily disturbed by the objects in the surroundings of receiver which reduces the accuracy in amplitude and phase of the receiving signal. As a result of the reflections of the signals, carrier phase multipath is caused which is the major problem at GPS receivers. Multipath is the propagation phenomenon in which the signals received by antenna other than line of sight signal is called multipath signal. Multipath signal is superimposed on the direct signal. GPS receivers provide the signal to noise ratio (SNR) used for estimation of multipath errors. Signal Quality Measurement is used for computation of phase error in the signal. In this paper we are using MUSIC algorithm to calculate the multipath parameter i.e amplitude and multipath phase. We are estimating the errors that are occurred due to the multipath which is further used to improve GPS signal precession.**

***Index Terms*: Global positioning system (GPS), MUSIC (Multiple Signal Classification), signal to noise ratio (SNR), signal quality, multipath.**

INTRODUCTION

Global Positioning System is the navigation system which provides position and time data using satellites. Multipath is the major problem at the GPS receivers which results in the delay, distortion, multipath parameter effects in the receiving signals and impacts on accuracy and precision of GPS positioning. The result due to the stream of signals arriving at the receiver, first the direct one, then a bunch of delayed reflected ones. This effect is called multipath effect. Multipath effect is vibrant in nature that depends on the weather conditions, reflecting surfaces, vicinity of GPS receiver.

Previously papers were published based on the receiver antenna design, reflectors design, filter design to reduce the multipath effect at receiver .All these methods describe the physical designing process that varies according to multipath effect which is vibrant in nature. In this paper, Signal and Data Processing technique as signal quality measurement is used for the estimation of the carrier phase multipath error. Signal to Noise Ratio (SNR) of the received signal is used for calculating the error. This method increases accuracy when compared to the previous methods. Many former papers described polynomial fitting technique that uses polynomial of degree 5-10 to separate direct signal from multipath signal but use of higher degree polynomial i.e above 4th degree is unstable and also widely diverges outside the range. To overcome the above limitations, this paper relies on the Multiple Signal Classification (MUSIC) algorithm used for the estimation of the composite signal amplitude at particular frequencies. Here the composite signal consists of both direct and indirect signal amplitude.

CARRIER PHASE MULTIPATH

This section describes carrier phase in GPS signals and how data is collected from the receiver. Reception of signal at receiver other than direct path from transmitter is called Multipath effect. Multipath effect depends on the vicinity of the receiver which includes buildings, surfaces, weather, altitude, type of antenna used for reception.etc.. These Multipath signals overlap on the direct signal causes changes in direct signal amplitude and also results in the phase change in carrier. Thus the accuracy in positioning and timing of the object reduces. The direct signal amplitude (AD) of the signal is always greater than multipath signal amplitude (AM). The composite signal which consists of both direct and indirect signal amplitude (AC) is also less than direct signal amplitude. Amount of reduction in amplitude with respect to direct signal is attenuation factor given as α called attenuation factor. Phase change between direct and multipath signal is given as $\delta\emptyset$. Multipath signal is shown in Figure-1.
Direct signal and indirect signal is shown in below Figure

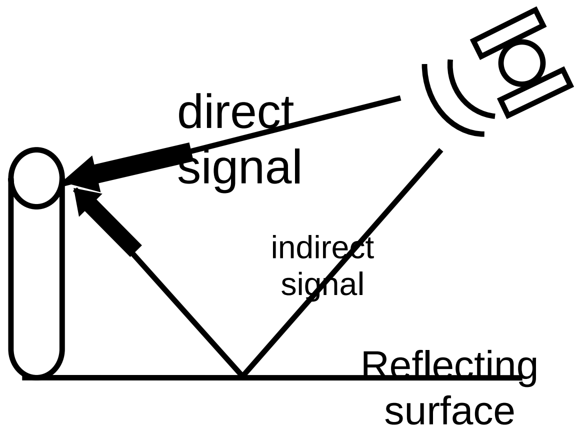

Figure-1. It shows the direct path signal from satellite and indirect signal due to reflecting surface

The phase change of the received signal with respect to the direct signal amplitude is shown in Figure-2.

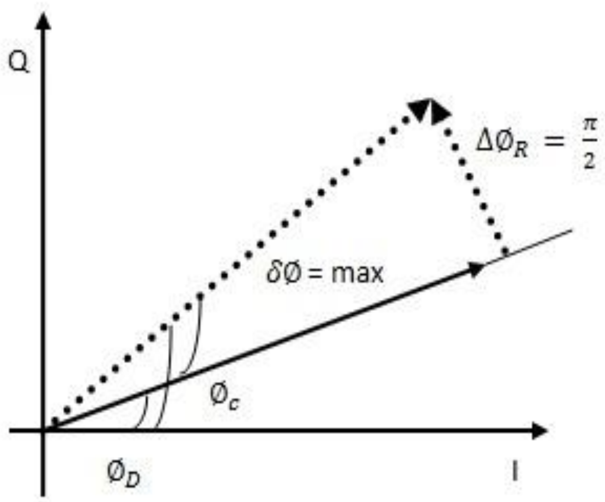

Figure-2. Phasor diagram of Inphase and Quadrature components of the signal.

The data from the receiver is collected in RINEX format and then is copied to excel sheet to plot the graph of SNR data. The data received consists of the SNR (dB), elevation angle (deg),azimutal angle (deg),Time, Satellite number (GPST). The data collected in plotted between SNR and number of samples in Figure-3.

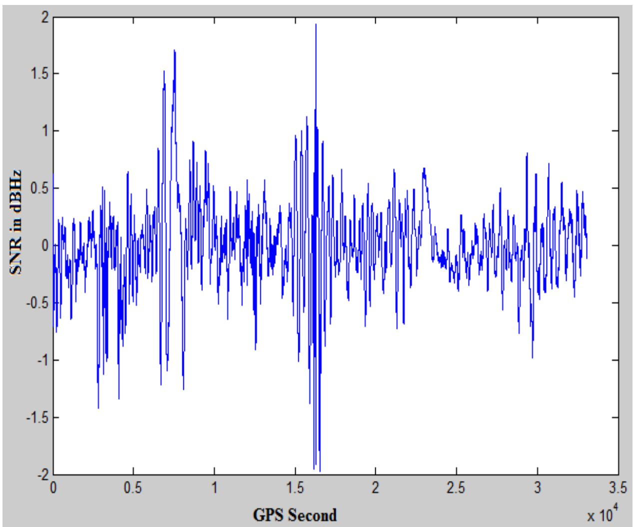

Figure-3. Normalised signal-to-noise ratiofor L1 of afull-arc pass of a GPS satellite. Plot between SNR (dBHz) in Y axis to number of samples in X axis. SNR data consists of direct and indirect signal values in dBHz.

CALCULATION OF COMPOSITE SIGNAL AMPLITUDE

MUSIC ALGORITHM (MULTIPLE SIGNAL CLASSIFICATION):

For detailed frequency analysis and the estimation of composite signal amplitude at particular frequencies MUSIC algorithm is used. It performs Eigen decomposition on covariance matrix of data to detect frequencies. It depends on orthogonality property which exists between noise vector and data vector. This algorithm gives more accurate output.

Let X be the data and number of frequencies in the received signal is assumed to be 'n'. The steps followed in MUSIC algorithm are.

a) Arranging the data in autocorrelation matrix with dimensions M x M where M>p+1, p are the number of samples in the input data. Assuming noise to be zero.

b) Calculate the eigen values [v,d] of the covariance matrix R where R is covariance of X , M

c) Sorting minimum value of the diagonal matrix and performing FFT with suitable radix to matrix.

d) Plotting the frequency response using Eigen Vector method involves normalizing the frequency using sampling frequency fs and the spectral peaks is given by

$$h(\omega) = \frac{1}{\sum_{i=0}^{m} |e^{H} v_i|^2} \quad (1)$$

where vi =itheigen value, $\omega = 2\pi f T_s$

'H' indicates Hermitian transpose

To implement MUSIC algorithm it is important to mention the autocorrelation matrix size and sampling frequency. As the matrix size increases computational complexity also increases.

We get frequencies and the composite signal amplitude from MUSIC algorithm implementation (composite signal amplitude is A_c and f is frequencies)

$$A_C = A_D + A_M \quad (2)$$

Where A_D = direct signal amplitude
A_M = Multipath signal amplitude

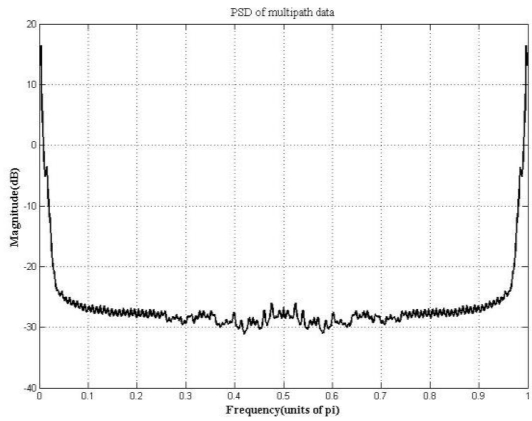

Figure-4. Spectrum analysis graph which includes frequencies and amplitude of the signal

SIGNAL QUALITY MEASUREMENT

RELATING SIGNAL QUALITY AND PHASE:

The signal strength is measured in terms amplitude or power ratio to figure the divergence of the received signal when compared to original signal. The strength of the signal depends on the type of the satellite, antenna Signal quality can be expressed in carrier to noise ratio or signal to noise ratio.

$$Q = \frac{A_C}{A_D} \quad (3)$$

Theoretical relation between A_C and A_D is $A_C = A_D\sqrt{1 + 2\,.\,\alpha\,.\cos\Delta\, \Phi_R + \alpha^2}$ (4)

α ($0 < \alpha < 1$) is attenuation factor and Φ_R is phase of composite signal with respect to direct signal.

Calculation of Q at different frequencies requires A_D which is assumed to be constant and composite signal amplitude A_C is obtained from the MUSIC algorithm as mentioned above.

Next we analyze the multipath phase error given by $\delta\Phi$ = -arcsin ($\frac{dQ}{d\Delta\Phi_R}$)

Where $\frac{dQ}{d\Delta\Phi_R}$ is the change in Q with respect to Φ_R. Change in Q is computed by subtracting following Q value with present Q value and dividing it with 10.Interms of attenuation factor theoretically it is given as

$$\frac{dQ}{d\Delta\Phi_R} = \frac{\propto \sin \Delta\emptyset_R}{\sqrt{1 + 2\alpha \cos \Delta\emptyset_R + \alpha^2}}$$

$$\delta\emptyset = \arctan \left(\frac{\alpha . \sin \Delta\emptyset_R}{1 + \alpha . \cos\Delta \emptyset_R} \right)$$

On solving above equation two equations we get

$$\frac{dQ}{d\Delta\Phi_R} = -\arcsin(\delta\emptyset).$$

Thus phase error is caluculated. Figure-4 containes graph of phase error.

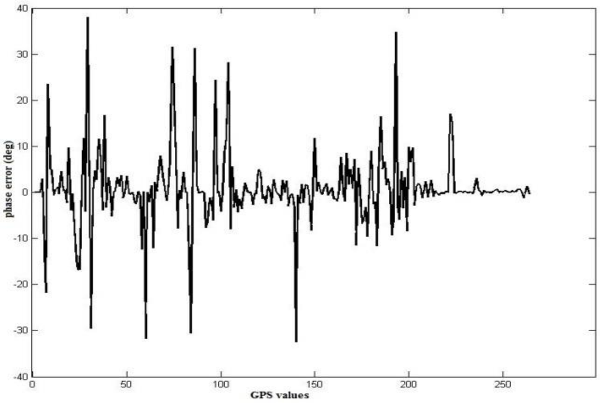

Figure-5. Graph of phase error with respect to time in seconds.

CONCLUSIONS AND FUTURE WORK

In this paper signal quality Q and carrier phase is related for carrier phase error and multipath amplitude estimation. For detailed frequency analysis Multiple Signal Classification algorithm is used. Theoretically multipath parameters are probable and easing techniques of multipath are analyzed.

We further extend our project to calculate phase error for different receivers simultaneously and to use one of the better techniques for multipath parameter estimation.

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