International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 6 Issue 04, April-2017

Phase Estimation Techniques for FMCW Radar

Chintan T. Gopani
Dept. of Electronics and Communication Engineering
CSPIT
Changa, India

Amit V Patel [1], Pradip I Panchal [2]
[1]Charusat Space Research and Technology Centre
[2]Dept. of Electronics and Communication Engineering
CHARUSAT, Changa, India

***Abstract*- In radar technology range information is getting from received signal which is reflected from the object, here received signal is measured with respect to the transmitted signal. Different radars are used to estimate the frequency and phase like Continuous Wave (CW) radar, Frequency Modulated Continuous Wave (FMCW) radar. To retrieve the phase information from transmitter and receiver we have implemented different techniques like Zero Crossing Detection (ZC), Fast Fourier Transform (FFT), and Hilbert Transform (HT) method. For simulating algorithm, MATLAB simulation tool is used to estimate the phase difference, and compared phase estimation techniques.**

Keywords: Zero-Crossing, Fast Fourier Transform, Hilbert Transform, and phase estimation

I. INTRODUCTION

Radio detection in ranging system is used for the estimation of distances of stationary and moving objects. The target distance can be measured with the use of two techniques either measuring the propagation delay of Electromagnetic (EM) reflected from the target object or it can be measured by amount of frequency or phase change between transmitted and received signal [1] [2] [3]. Number of techniques are there for the implementation of radar like CW and FMCW radar. Generally FMCW radar is used for distance measurement moving target object. The FMCW radar modulation is compatible with variety of solid state transmitters frequency measurement is used to obtain range measurement. The power consumption of FMCW radar is low and frequency measurement can be perform digitally based on FFT. Received and transmitted signals are very difficult to detect with established intercept receivers [2] [3]. Whereas CW radar radiates continuous transmission power. In contrast to FMCW radar CW radar cannot change its operating frequency during the measurement. CW radar device without frequency modulation have the disadvantage that it cannot determine the target range, less accuracy of range measurement compared to FMCW radar [2] [3]. There are various method proposed for measuring phase difference between two signals like Zero-Crossing detection method, Fast Fourier Transform method, Hilbert Transform method, Cramer-Rao Lower Bound method, Interpolation method.

Zero-crossing detection is a common method for measure the frequency, phase and amplitude of the signal [4]. In zero crossing detection method measuring multiple periods helps to reduce errors caused by phase noise by providing disturbance in ZC method. In different literature various methods are presented to minimize the error measurement like ZC implementation using DFT (Discrete Fourier Transform), by digital means ZC detection using XOR operation between two signals [5].

FFT method can use to achieve high resolution and accuracy. FFT is described for estimation of the frequency, amplitude and phase of a sinusoidal signal from its samples. FFT gives the very sharp waveform at every collection of intervals. So, Phase estimation is also become easy using FFT [5] [6]. FFT is based on maximum likelihood estimation is a well suitable technique. It can be also implemented using interpolation method. FFT procedure tell that collected signals are continuously present for an infinite time [7]. During the operation spectral lines and inacceptable error occurred that prevention by filter. From literature survey various methods are used for FFT implementation like estimation to the frequency of sinusoidal signal using FFT, estimation the Frequency of millimeter wave using LFMCW (Linear FMCW) radar based on FFT, frequency estimation based on piecewise FFT [8].

Hilbert Transform is use for the removal of problem caused by above techniques. Hilbert Transform used to measure the phase and frequency. In ideal case this method gives $\pm\Pi/2$ phase shift of reference signal [10]. Presently, the phase difference estimate techniques are DFT spectrum analysis, Zero-crossings, vector inner product, digital correlation. The based on DFT spectrum analysis need complete sampling of the signal and sometimes zero-crossing method is also not reliable because if there is noise than superimposed over the measured signal. Whereas digital correlation and vector inner product is depends on sampling frequency but HT is better than these techniques [11].

In this paper we have implemented ZC detection method, FFT method and HT method for the estimation of phase difference between two signals using MATLAB simulation tool. The phase is measured between 100 KHz reference signal and received signal. This paper is organized as follows. Section II is illustrated the literature of different measurement techniques. Simulation results of three different techniques is illustrated in section III, followed by conclusion and references.

II. LITERATURE SURVEY

1. Hilbert Transform [9]

For the implementation of HT steps are followed, (I) Reference signal is transformed by 90º phase with the use of HT, (II) Original signal is multiply by referenced signal and transformed signal is multiply by original signal, and (III) Measure the phase difference between referenced and measured signal. We get the $\pm\Pi/2$ phase shift of original sinusoidal signal using Hilbert transform technique. The phase difference is calculated through triangle transform and some simple operations. Hilbert transform of the signal $x(t)$, is defined as:

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 6 Issue 04, April-2017

$$\hat{x}(t) = \left(\frac{1}{\Pi}\right) \int_{-\infty}^{+\infty} \frac{x(\tau)}{t-\tau}\, d\tau = x(t) * \frac{1}{\Pi\tau} \qquad (A)$$

There are many properties of Hilbert Transform, in which the ±Π/2 phase shift property is one. For instance, sin (ωt) is the Hilbert transform of cos (ωt) and vice versa.

1.1 Phase Difference Measurement

For two cosine signals with the same frequency.

$$x_1(t) = A_1 \cos\big(2\Pi f_0 t + \emptyset_1(t)\big) \qquad (1)$$

$$x_r(t) = A_2 \cos\big(2\Pi f_0 t + \emptyset_2(t)\big) \qquad (2)$$

Where; A_1 and A_1 are amplitudes
f_0 is the frequency
$\emptyset_1$ and $\emptyset_1$ are phase varying with time
$x_1(t)$ is the reference signal

Our aim is to evaluate the phase with respect to reference signal. According to ±Π/2 phase shift, we get $\hat{x}_r(t)$

$$\hat{x}_r(t) = A_2 \cos\big(2\Pi f_0 t + \emptyset_2(t)\big) \qquad (3)$$

From the Hilbert Transform system block diagram, we get the phase angle $\emptyset$

$$\emptyset = \arctan\left(\frac{y_{ht}}{y}\right) \qquad (4)$$

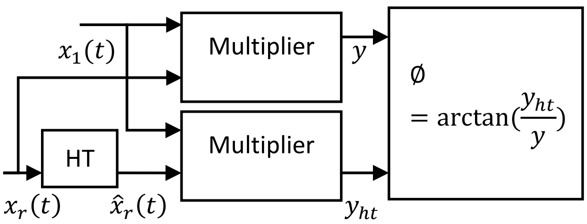

Fig 1. System block diagram of Hilbert Transform

2. Zero-crossing Detection

Zero crossing detection is the most common method for measuring the frequency and phase [4]. This method specifically focus on delay between sample points of reference signal and received signal. Each positive to negative zero-crossing of signal $x_1(t)$ and each negative to positive zero-crossing of signal $x_1(t)$ gives the number of crossing points. Measure the number of samples between the two zero-crossing points which tells about signal frequency. For estimate the frequency take the inverse of ratio of number of samples of a single period to the sampling frequency.

3. Fast Fourier Transform

Generally in DFT requires large number of computations. It used direct computation. So, it required large computation time. For the computation of N point DFT, N^2 complex multiplication $N^2 - N$ complex additions are required. If the value of N is large then number of computations are be more, so inefficiency is occurred in DFT computation. To overcome this FFT algorithm is used. For computations of N point FFT, (N/2)$\log_2 N$ complex multiplications and $(N * \log_2 N)$ complex additions are required. So, FFT is better than DFT.

III. SIMULATION AND RESULTS

As per requirement to liquid level measurement application 100 KHz reference signal is used which is sampled by 2.5MSPS sampling rate and measured the phase difference of the received signal.

1. Hilbert Transform (HT)

Estimated phase difference between the measured signal and reference signal is shown in table1. Measured phase difference is 4.6489º and 4.4066º of 98.999 KHz and 95 KHz received signal, respectively. Hilbert Transform of the reference signal and measured signal is shown in the below figure.

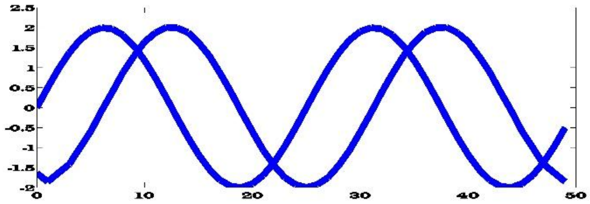

Fig 2. Hilbert Transform of the 100 KHz signal

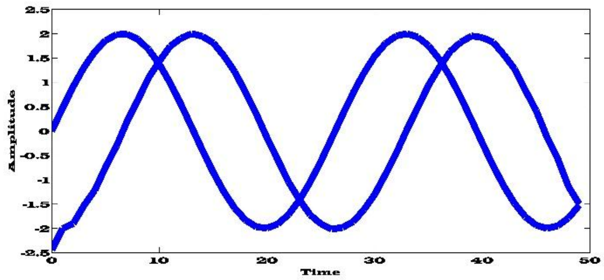

Fig 3. Hilbert Transform of the 95 KHz signal

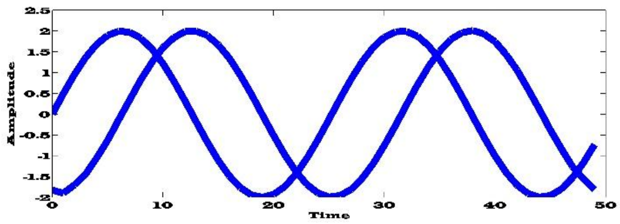

Fig 4. Hilbert Transform of the 98.999 KHz signal

2. Zero-crossing Detection (ZC)

Frequency is also estimate using this technique but main concern only on phase. Fig 5, Fig 6 and Fig 7 demonstrate the simulated response of the reference signal, measured signal. Measured phase difference of received signal with respect to reference signal is shown in the table1. Estimated phase difference is 1.5512º and 1.5669º of 99 KHz signal and 98 KHz received signal, respectively.

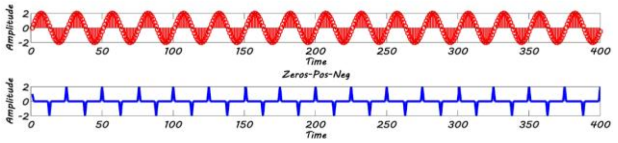

Fig 5.Sample version and zero-crossing of the 100 KHz signal

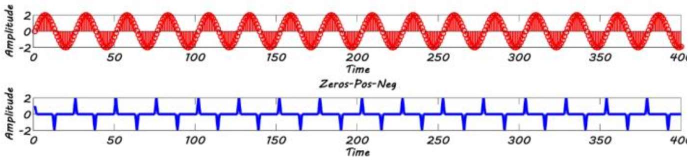

Fig 6.Sample version and zero-crossing of the 99 KHz signal

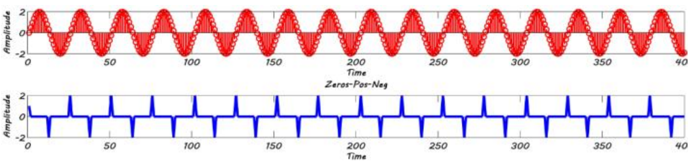

Fig 7.Sample version and zero-crossing of the 98.999 KHz signal

3. Fast Fourier Transform (FFT)

Fig 8 is shown the FFT of the measured signal to estimate the phase difference with respect to reference signal. By using FFT, estimated phase difference are occurred 0.3516^{o} and 0.3517^{o} of the measured signal of 98.999 KHz and 95 KHz signal, respectively.

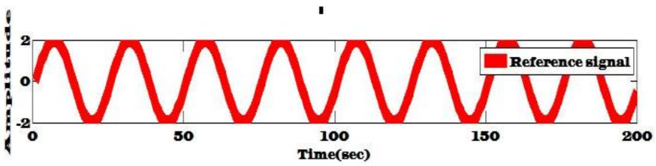

Fig 8. Waveform of the reference, measured and deviated signals

Techniques	Phase Difference (in Degree)	Received Signal Frequency(in KHz)
FFT	0.3516	98.999
	0.3516	99
	0.3517	95
	0.3517	97
	0.3516	98.005
HT	4.6489	98.999
	4.6489	99
	4.4066	95
	4.5258	97
	4.5871	98.005
ZC	1.5669	98.999
	1.5512	99
	1.5669	95
	1.5590	97
	1.5590	98.005

Table 1. Compare phase difference of received signal using different techniques

IV. CONCLUSION

Received signal is sensed by FMCW radar with varied frequency due to change the liquid level which has different phase angle. Phase estimation techniques like HT, ZC, and FFT are used to estimate the phase difference between reference signal and received signal. Out of these techniques FFT gives better phase difference i.e. lower phase difference compared to other techniques whereas HT technique gives major phase difference. So, FFT is suitable technique to estimate the phase difference.

REFERENCES

[1] Xin Wu, Nianzu Zhang et.al. “Frequency Estimation Algorithm for Ranging Of Millimeter Wave LFMCW Radar”, *IEEE*, 2016.

[2] Dr.A.G.Stove, “Modern FMCW Radar - Techniques and Applications”, European Radar Conference, 2004.

[3] A.G.Stove, “Linear FMCW radar techniques”, *IEEE*, Vol. 139, No.5, October, 1992.

[4] R.W. Wall, “Simple Methods for Detecting Zero Crossing”, Senior Member, *IEEE*, 2012.

[5] Predrag Ninkovic, “A Novel Real-Time Magnitude And Frequency Estimation Method Using DFT Zero-Crossings”, *IEEE*, 2014.

[6] Lei Fan, Guoqing Qi, Wenbo He, “Accurate Estimation Method of Sinusoidal Frequency Based On FFT”, Proceedings of the 35th Chinese Control Conference July 27-29, Chengdu, China, 2016.

[7] Huang Xiaohong, Wang Zhaohua, Hou Guoqiang, “New Method of Estimation of Phase, Amplitude, and frequency Based on all Phase FFT Spectrum Analysis”, *IEEE*, 2007.

[8] Mans Klingspor, “Hilbert Transform: Mathematical Theory And Applications To Signal Processing”, November 19, 2015.

[9] Huiyue Yang, Yaqing Tu, Haitao Zhang1, Kanghui Yang, “A Hilbert Transform Based Method for Dynamic Phase Difference Measurement”, 24th Chinese Control and Decision Conference (*CCDC*), 2012.

[10] Denis Donnelly, “The Fast Fourier and Hilbert-Huang Transforms: A Comparison”, International Journal of Computers, Communications & Control, Vol.1, pp. 45-52, 2006.

C. S. Burrus, “Teaching the FFT Using Matlab”, *IEEE*, 1992.

[11] Sergio Rapuano and Fred J. Harris, “An Introduction to FFT and Time Domain Windows”, *IEEE* Instrumentation & Measurement Magazine, December, 2007.