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Study of Frequency Offset in SDR Communication System

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Abstract: Software Defined Radio (SDR) is sometimes radio has been the aim of many radio developments. The military and civilian radio applications digital radios are used instead of analog radios. SDR is also defined as "Radio in which some or all the physical layer functions are software defined". Software defined radio plays a major solution for the need for flexibility, upgradability, and the problems of implementing multiple radio standards alternatively and even running several services in parallel. BPSK and QPSK technique is used in carrier synchronization by software defined radio. The performance of the system is investigated by applying Binary Phase Shift Keying (BPSK) and Quadrature Phase Shift Keying (QPSK) modulation techniques and Frequency Offset (FO) is observed by using the constellation diagram. Fine frequency correction technique is used for the reduction of frequency offset and better performance.

Index Terms **– SDR, BPSK, QPSK, FO.**

I. INTRODUCTION

Various forms of communication have evolved over the millennia. The spoken word can be transmitted from one person, and heard or received by another. In modern times town criers hold an annual contest to discover who can shout a comprehensible message over the greatest distance. However, while the world record is for loudest crier is 112.8 decibels, it can only be understood at less than 100 meters. The desire to communicate more effectively than shouting, is old as speech itself. With modern advances in computing technologies, digital signal processing and digital communication algorithms, artificial intelligence, radio frequency (RF) hardware design, networking topologies, and many other elements have evolved modern communication systems into complex, intelligent, high-performance platforms that can adapt to operational environments and deliver large amounts of information in real-time, error-free. The latest step in communication systems technology is the software-defined radio, or SDR, which adopts the most recent advances in all fields to yield the ultimate transmitter and receiver. An SDR system is a complex device that performs several complicated tasks simultaneously in order to enable the seamless transmission and reception of data. In general, a digital communications system consists of an interdependent sequence of operations responsible for taking some type of information, whether it is human speech, music, or video images, and transmits it over-the-air to a receiver for processing and decoding into a reconstructed version of the original information signal. If the original information is analog (like audio), it must first be digitized using techniques such as quantization in order for us to obtain a binary representation of this information. Once in a binary format, the transmitter digitally processes this information and converts it into an electromagnetic sinusoidal waveform that is uniquely defined by its physical characteristics, such as its signal amplitude, carrier frequency, and user of the spectrum is not using it, an SDR can borrow the spectrum and assign it to a secondary user until the owner requires it again phase (Meyr, M. Moeneclaey et.al, 1998,] B. Sklar,1988, The Mathworks Inc,1999).. This technique has the potential to dramatically increase the optimal use of available spectrum.

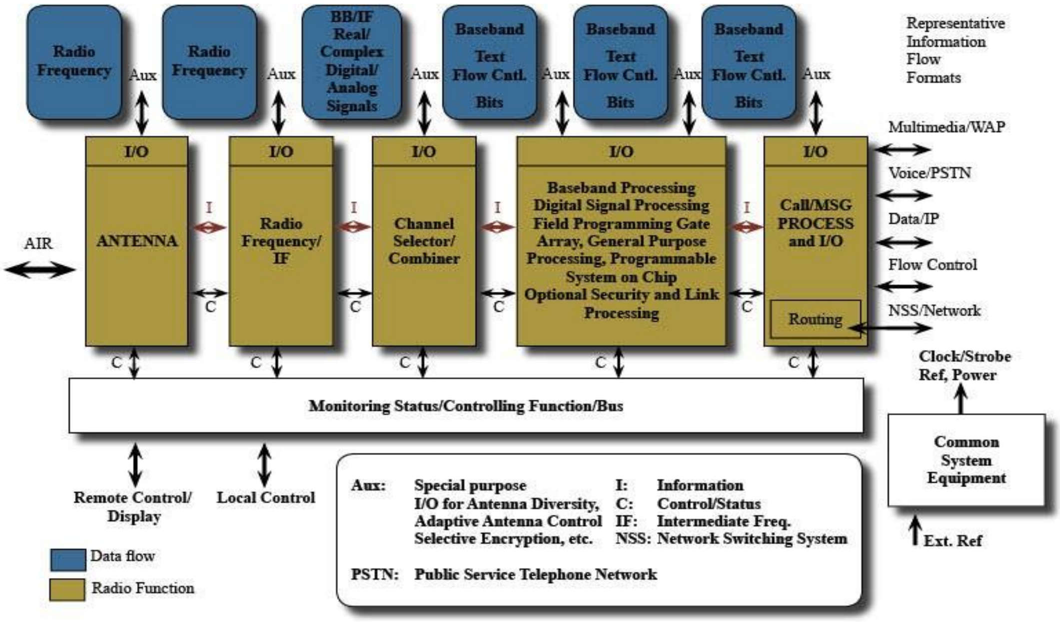

Fig.1 Block diagram of Communication System

ADVANTAGES OF SDR

i. Compactness and power efficiency

The software radio approach, however, results in a compact and in some cases, a power-efficient design. As the number of functionalities increase, same piece of hardware is reused to implement multiple interfaces thus less number of different hardware components are required as well as power consumption is lowered.

ii. Ease of upgrades

In the course of deployment, current services may need to be updated or new services may have to be introduced. A flexible architecture of SDR allows improvements and addition of already existing or new functionality through software only instead of replacing the hardware platform or user terminals.

DISADVANTAGES OF SDR

i. Analogue to digital converters limit top frequencies that can be used by the digital section.
ii. For very simple radios the basic platform may be too expensive.
iii. Development of a software defined radio requires both hardware and software skills.
iv. Poor dynamic range in some SDR prototype designs.
v. It is difficult to write software to support different target platforms.
vi. SDR architecture consists of analog RF front end and digital front end. Hence it is challenging to implement interfacing between analog and digital modules or blocks.
vii. For few simple radio system designs, SDR platform may be expensive

[V.J. Arkesteijn, E.A.M. Klumperink, et.al, 2002; S. Armour, M. Butler,et.al, May 2002; J. Medbo and P. Schramm, 1998].

II. APPLICATIONS OF SDR

i. Mobile communications

Software defined radios are very useful in areas such as mobile communications. By upgrading the software, it is possible to apply changes to any standards and even add new waveforms purely by upgrading the software and without the need for changes to the hardware.

ii. Research & development

The software defined radio, SDR is very useful in many research projects. The radios can be configured to provide the exact receiver and transmitter requirements for any application without the need for a total hardware design from scratch.

iii. Military

The military have made much use of software defined radio technology enabling them to re-use hardware and update signal waveforms as needed.

iv. SDR for Android

One of the platforms for which SDR applications have been developed is Android. The software SDR Touch turns the phone in to a SDR receiver whose range fluctuates between 50MHz and 2 GHz in AM, FM and SSB depending on the used hardware. There is also another software called Pocket HAM Bands Transceiver who allows the remote listening of SDR receivers.

v. Amateur Radio

Radio hams have very successfully employed software defined radio technology, using it to provide improved performance.

vi. Commercial applications

[S.A. Fechtel, G. Fock, 1999; R. van Nee, 2000; L. Hanzo, T. Keller, and W. Web, 2000,Wang, Y., K. Shi, et.al (2004);F. J. Harris and M. Rice, 2001]

III. FREQUENCY OFFSET AND FREQUENCY OFFSET CORRECTION TECHNIQUE

In radio engineering, a frequency offset is an intentional slight shift of broadcast radio frequency (RF), to reduce interference with other transmitters. frequency offset often occurs when the local oscillator signal for down-conversion in the receiver does not synchronize with the carrier signal contained in the received signal. This phenomenon can be attributed to two important factors: frequency mismatch in the transmitter and the receiver oscillators; and the doppler effect as the transmitter or the receiver is moving [U. Mengali and A. N. D'Andrea,1997; J. P. Hoffbeck, 2012; F. Harris, C. Dick,2000; A.Priya, Rajesh, et.al, 2013].

When this occurs, the received signal will be shifted in frequency. For an wireless communication system, the orthogonality. among sub carriers is maintained only if the receiver uses a local oscillation signal that is synchronous with the carrier signal contained in the received signal. Otherwise, mismatch in carrier frequency can result in inter-carrier interference (ICI). The oscillators in the transmitter and the receiver can never be oscillating at identical frequency. Hence, carrier frequency offset always exists even if there is no Doppler effect.

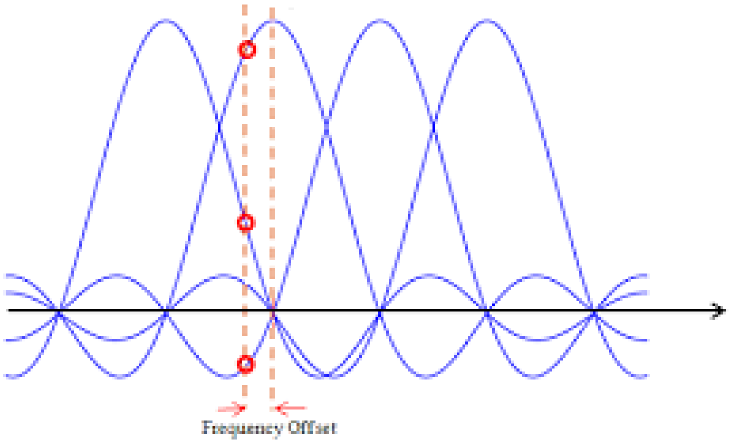

Fig.2 Frequency Offset

The frequency correction technique used reduction of frequency offset are as follows

i. Coarse Frequency Offset Correctio.
ii. Fine Frequency Offset Correction.

In this paper, the correction technique used is fine frequency correction technique in order to reduce frequency offset.

Fine frequency correction (FFC), also called carrier phase correction, should produce a stable constellation for eventual demodulation. Essentially this will drive the remaining frequency offset of the received signal to zero. Correction can be described by producing a stable constellation due to how fine frequency offset effects are typically examined with a constellation diagram. discrete digitally modulated signal exhibits frequency offset, this will cause rotation over time as examined in a constellation diagram. This effect where each number relates a sample's relative occurrence in time, which provides this perspective of rotation. The signal itself is BPSK, causing it to jump across the origin with different source symbols. If a positive frequency offset is applied the rotation will be counterclockwise and clockwise with a negative offset. The rate of the rotation is equal to the frequency offset. The equation for fine frequency offset is expressed as

$$\alpha_{LT} = \frac{1}{64}\angle\left(\sum_{i=0}^{63} \overline{S[i]}S[i+64]\right) \quad \text{Eq. (1)}$$

The intuition is the phase difference between S[i] and S[i+16] represents the accumulated CFO over 64 samples.

IV. RESULTS AND DISCUSSION

In this paper, the study of frequency offset is done at the receiving end where SDR is applied. Frequency offset occurred due to the mismatch of frequencies at local oscillator. Hence the observations of offsets is done by applying different modulation techniques like BPSK and QPSK. The observation id done using constellation diagrams for the offset and also for fine frequency correction technique which is applied for reduction of frequency offset.

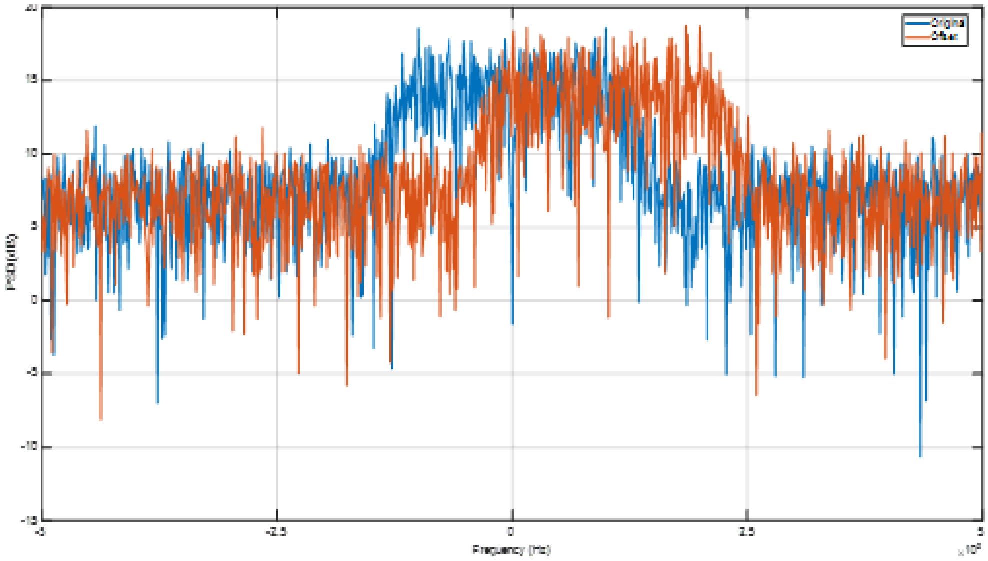

Fig.3 Spectrum Analyzer result for both original and offset using BPSK modulation

The above figure Fig.3 shows the performance of the system with original signal spectrum and spectrum with offset. The modulation technique applied is BPSK. From the above figure it is observed that there is a shift in the spectrum and the spectrum (indicated with red color) when compared with original spectrum (indicated with blue color) it is observed that there is shift in spectrum caused due to frequency offset. The taken parameters for the system is Sample Rate at 1KHz, Samples Per Symbol is 1, Frame Size is 2^{10},Number of Frames is 300, Modulation applied is BPSK.

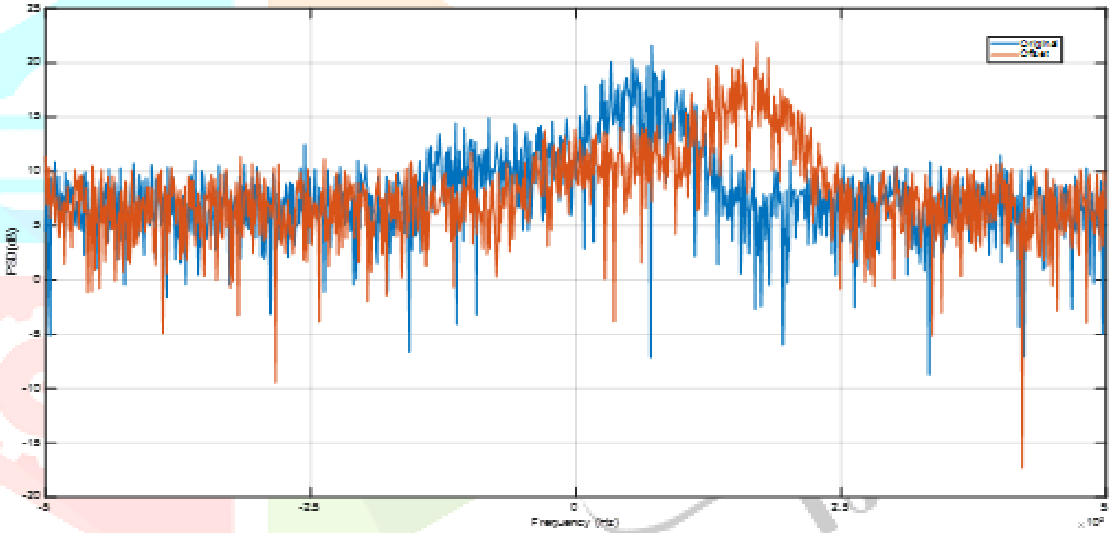

Fig. 4 Spectrum Analyzer result for both original and offset using QPSK modulation

The above figure Fig.4 shows the performance of the system with original signal spectrum and spectrum with offset. The modulation technique applied is QPSK. From the above figure it is observed that there is a shift in the spectrum and the spectrum (indicated with red color) when compared with original spectrum (indicated with blue color) it is observed that there is shift in spectrum caused due to frequency offset. As the order of the modulation increases the frequency offset also increases. The taken parameters for the system is Sample Rate at 1KHz, Samples Per Symbol is 1, Frame Size is 2^{10}, Number of Frames is 300, Modulation applied is QPSK.

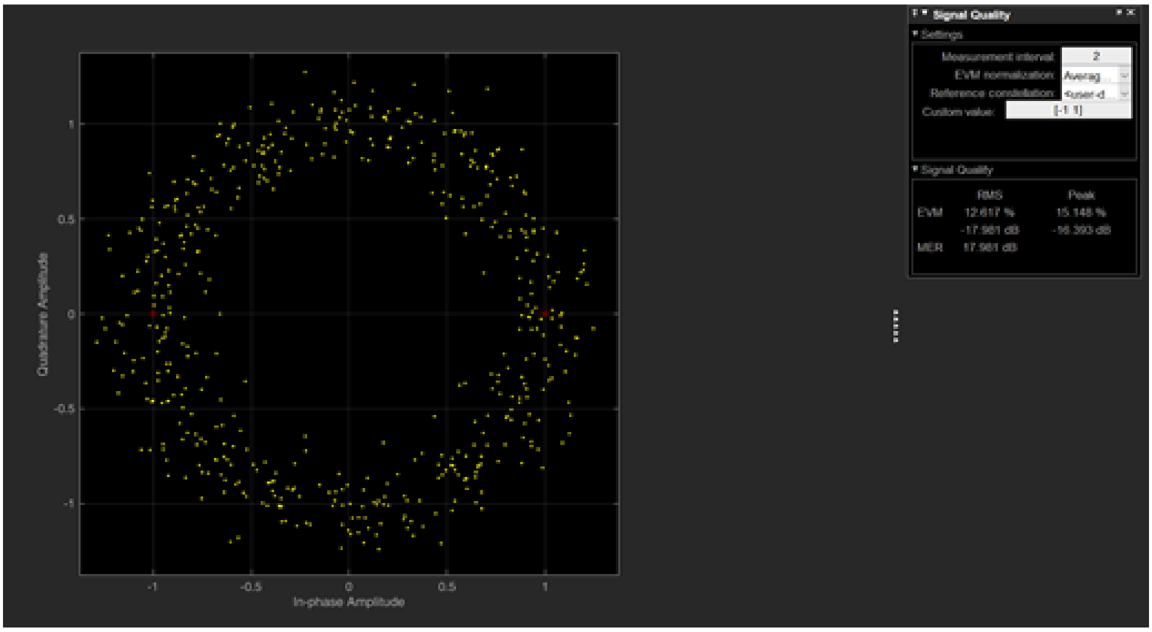

Fig.5 Signal quality of the baseband constellation with frequency offset using BPSK

The above figure Fig.5 shows signal quality of the baseband through the constellation diagram of the system with frequency offset. The modulation technique applied is BPSK. The below figure Fig.6 shows the signal quality of the baseband through the constellation diagram of the system without frequency offset using fine frequency correction. The modulation technique applied is BPSK.

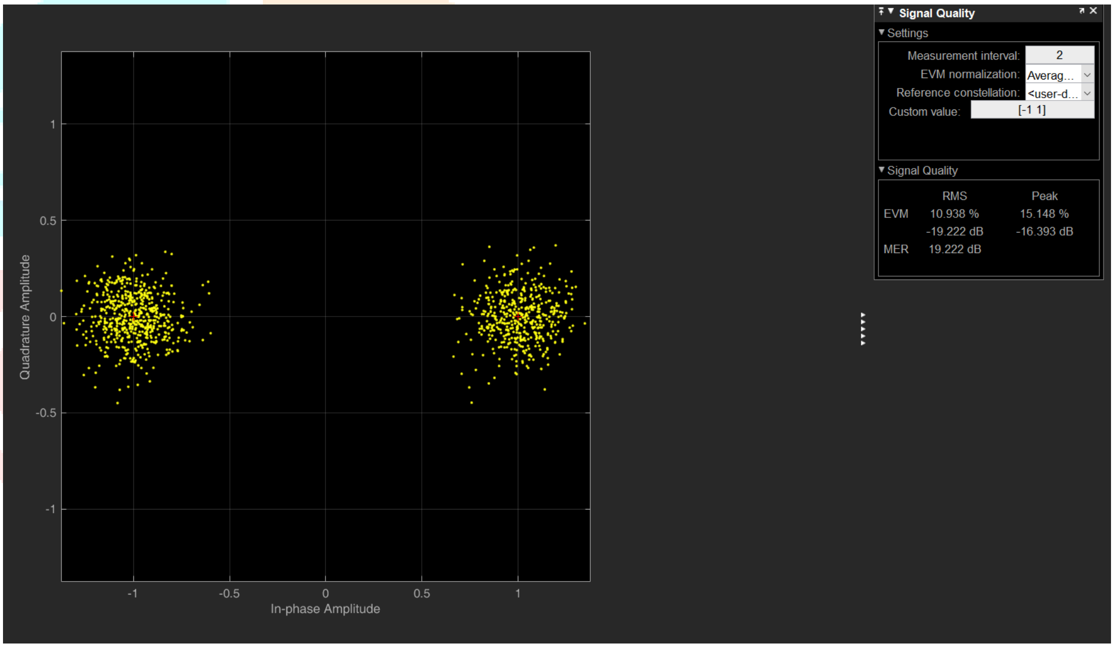

Fig.6 Signal quality of the baseband constellation without frequency offset using finite frequency correction

The below figure Fig.7 shows signal quality of the baseband through the constellation diagram of the system with frequency offset. The modulation technique applied is QPSK. The figure Fig.8 shows the signal quality of the baseband through the constellation diagram of the system without frequency offset using fine frequency correction. The modulation technique applied is QPSK.

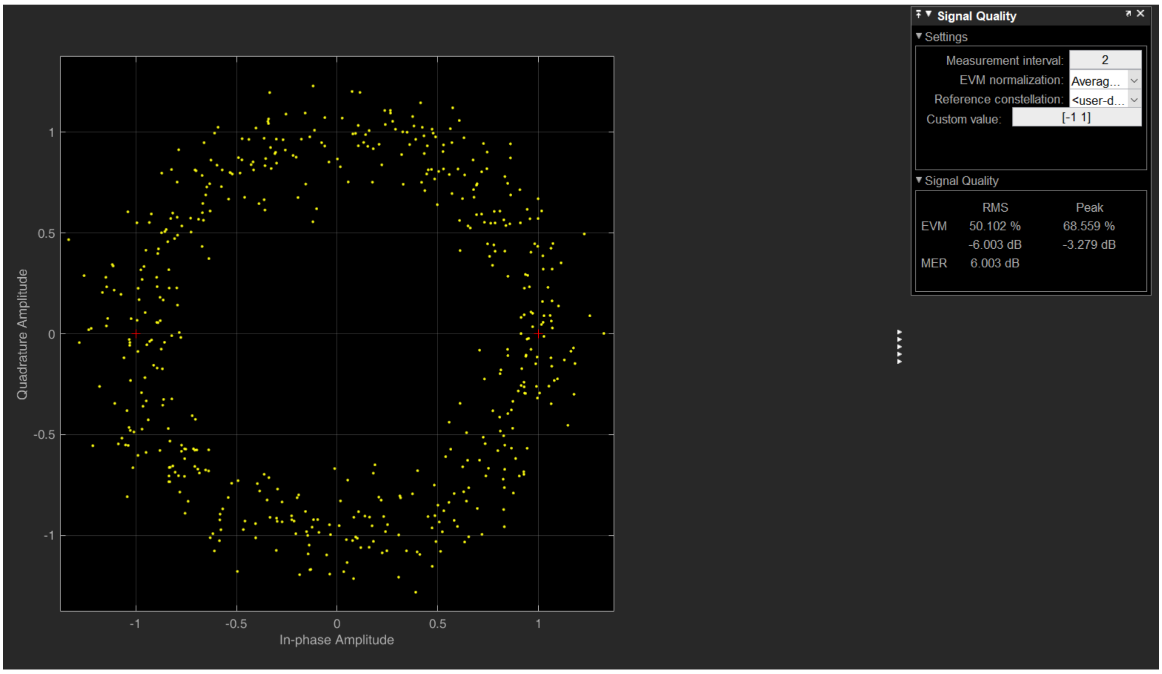

Fig.7 Signal quality of the baseband Constellation with frequency offset using QPSK modulation

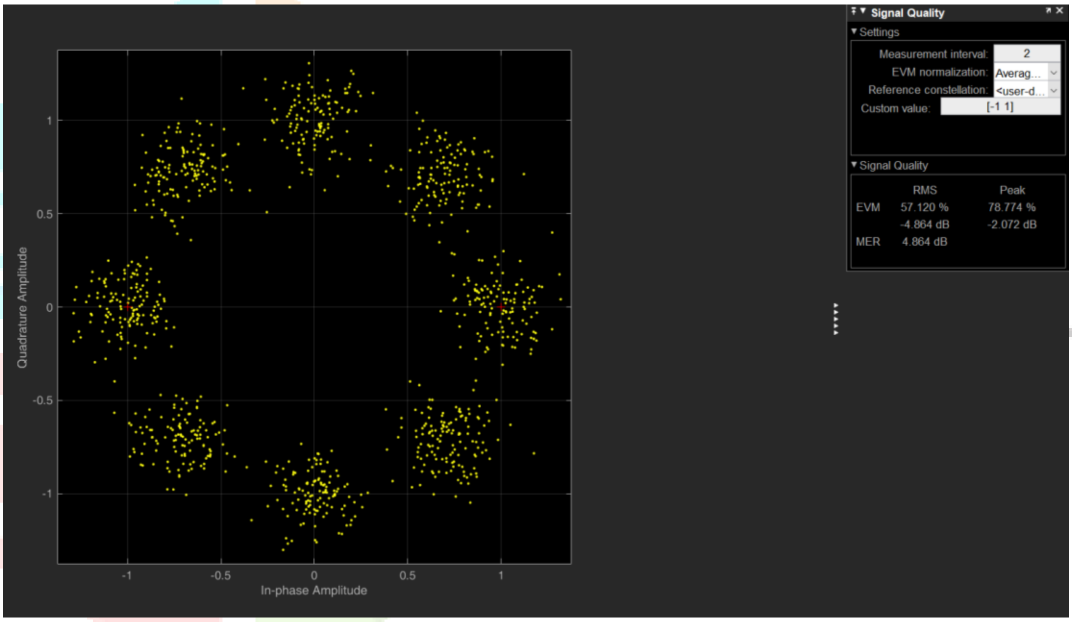

Fig.8 Signal quality of the baseband Constellation without frequency offset using QPSK modulation by applying fine frequency correction

V. Conclusion

This paper studies the performance of the system and frequency offset, also the reduction of offset using correction technique. The performance of system is observed for various modulation techniques like BPSK and QPSK through constellation diagram for the signal with frequency offset and without offset i.e offset reduced using fine frequency correction.

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