Performance Comparison of Optimised Qpsk Modulator with Msk Modulator in Vhdl

Prof. P. Subba Rao, V. Geetanjali, N. Durga Naga Lakshmi

Abstract: Quadrature PSK (QPSK) modulation is a prevalent and well spread digital modulation technique. QPSK Modulator was implemented using the CORDIC algorithm with reduction in area and delay than other conventional QPSK modulators. The main problem encountered with QPSK modulator is that phase continuity is not maintained. This problem is removed in another modulation technique called Minimum Shift Keying (MSK). The performance comparison between CORDIC based QPSK modulator and MSK modulator is done which led to the enhancement of some parameters such as area and delay which decide the performance of modulator. The design of both of these modulation techniques were implemented using Xilinx ISE software version 14.5 in VHDL using the Spartan 3E starter kit device.

Index Terms: CORDIC, cosine, Minimum Shift Keying, Quadrature PSK, sine.

I . INTRODUCTION

Due to the recent innovations in mobile technology and cable less data transfers, the basis for communication between different systems today relies on communication without cables (wires). But data rate required must be high for wireless communication which can be done by using digital modulation methods. Among other modulation techniques, 4-PSK or Quadrature PSK is the most prevalently used one. In several wireless radio transmissions such as RTTY Radio Teletype Transmissions and in applications where lesser bandwidth is required QPSK modulation is used [1]. In QPSK modulation technique, input bit sequence is observed and the phase is changed keeping frequency and amplitude the same. The QPSK signal is generated by observing two bits of the input signal which are consecutive. First bit of the input data gives the component which is in same phase (cosine) component and the second bit of the input data gives the opposite phase (sine) component. Corresponding to two input bits, we get four phases in QPSK modulator. The QPSK generated signal shows better results in information rate which is twice as that of BPSK signal. QPSK exhibits less bit rate than QAM and other higher order digital modulation techniques, but its less intricate circuit design makes it more popular. The implementation of QPSK Modulator with the aid of CORDIC Algorithm is also illustrated. CORDIC Algorithm generates sine-cosine carriers simultaneously in rotation mode and it acts as rectangular-polar conversion in vectoring mode. The main advantage of CORDIC Algorithm is it replaces LUT based generation of carrier [2].

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MSK is a useful digital modulation technique which can be consequential from OQPSK as a distinct instance of Continuous Phase FSK (CPFSK). It is a form of continuous phase modulation system where phase continuity is maintained [3].

II .QPSK MODULATOR IMPLEMENTATIONS

A. General QPSK Modulator

In Quadrature PSK modulation, division of input binary sequence into two streams is done by means of a de-multiplexer. The resultant unipolar data is encoded in Non-Return to Zero (NRZ) format. The encoded data is modulated with large frequency carrier wave as shown in Fig. 1. These waves are assorted with di-bit (odd and even) streams to engender an in-phase (cosine) and a quadrature phase (sine) component respectively. Finally, addition of these two phases is done using an adder to form a QPSK modulated wave.
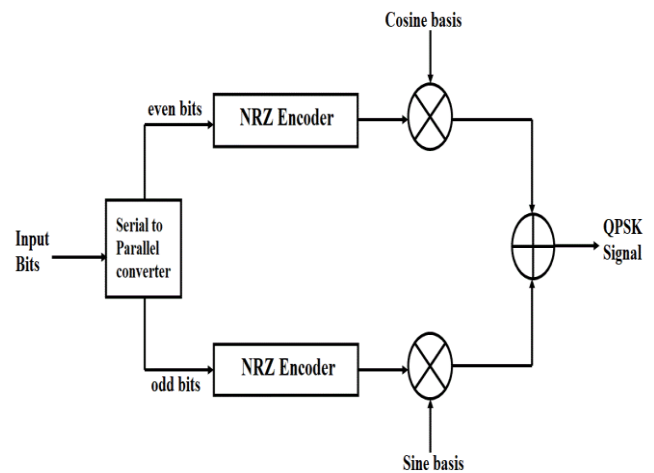

Fig. 1: Block diagram of QPSK Modulator

The mathematical equation of QPSK modulated data is presented in Eq. 1, where f_c is the number of times carrier wave has appeared per second, E_s is energy per symbol and T_s is symbol period [1]:

$$Q\ (t) = \sqrt{\frac{2E_s}{T_s}}\ \cos\ (2\pi fct + \frac{(2i-1)}{4}\pi)\ \ (1)$$

Where i = 1,2,3,4

Blocks of RAM are utilized to stock the readings of intermediate results in case of digital QPSK modulator. The values stored are then added with their respective signs based on the di-bit input by generating phase readings for the required output signal.

Table I shows different phases of different di-bit combinations for generating a QPSK signal.

Table I : I and Q phase for QPSK output signal			
1st Bit	2nd Bit	I-phase	Q-phase
0	0	$-\cos(\omega_c t)$	$-\sin(\omega_c t)$
0	1	$-\cos(\omega_c t)$	$\sin(\omega_c t)$
1	0	$\cos(\omega_c t)$	$-\sin(\omega_c t)$
1	1	$\cos(\omega_c t)$	$\sin(\omega_c t)$

B. CORDIC ALGORITHM

CORDIC denotes Coordinate Rotation Digital Computer Algorithm, is an efficient and simple algorithm that performs addition, subtraction and binary shift and LUT operation. The Fig. 2 shows proposed CORDIC based IQ modulator which avoids large sized LUTs.
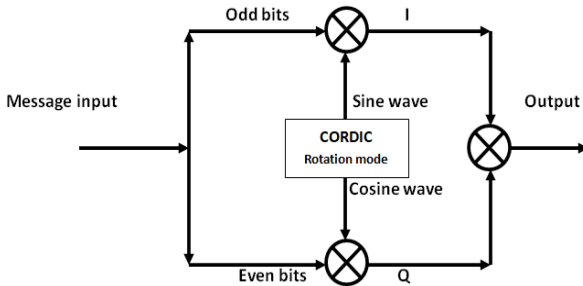

Fig. 2: Proposed CORDIC based IQ Modulator

The principle of vector rotation transforms in CORDIC algorithm [5]. It is used to calculate all the mathematic functions. Method of iterations is used in this algorithm to perform the rotation of vector by accomplishing shifting and adding operation [4], [5]. The equations of the vector rotation acquire this algorithm [4], [5]:

$$x' = x\cos\varphi - y\sin\varphi \quad (2)$$
$$y' = y\cos\varphi + x\sin\varphi \quad (3)$$

The angle φ is taken as the sum of small angles in such a way that their tangents are all inverse power of two. These equations can be easily implemented with the aid of an adder, subtractor, binary shifter and LUT. The equations (2) and (3) are rearranged as [4], [5]:

$$x' = \cos\varphi[x - y\tan\varphi] \quad (4)$$
$$y' = \cos\varphi[y + x\tan\varphi] \quad (5)$$

The exponentiation task with the tangent term is merely transformed to shift action by taking the rotation angle as $\tan(\varphi) = \pm 2^{-i}$. Based on the vector rotation at each iteration i, the decision regarding direction is considered [4], [5]:

$$x_{i+1} = K_i[x_i - y_i . d_i . 2^{-i}] \quad (6)$$
$$y_{i+1} = K_i[y_i + x_i . d_i . 2^{-i}] \quad (7)$$

Where,

$$K_i = \cos(\tan^{-i}2^{-i}) = \frac{1}{\sqrt{1 + 2^{-2i}}} \quad (8)$$
$$d_i = \pm 1$$

By the direction of rotation of angle, the value of d_i is determined.

In this particular design, rectangular to polar conversion is executed which can be done using the mode of vectoring of the CORDIC Algorithm.

III .MSK MODULATOR

MSK is a powerful modulation technique which has special characteristics of providing continuous phase and constant envelope. The main advantage of MSK technique is that it is more immune to noise on amplitude and phase change. Because of this advantage, MSK modulation technique is used more often in every communication field compared to other modulation technique such as BPSK and QPSK. The MSK Modulation can be realized using two ways. One is IQ Based Concept and the other is Direct MSK Approach. In both reduced by means of Pulse Shaping. This Pulse Shaping of bits at the input gives smooth transition of phase with no offsets at the end of the bit by maintaining constant envelope [6].

The mathematical equation for MSK signal is represented as [7]

$$S_{MSK} = \cos(2\pi f_c t \pm \frac{\pi}{2T_s} t + \emptyset_0) \quad (9)$$

Minimum Shift Keying Modulation technique can be referred to as Orthogonal QPSK where direct modulation of both the channels (I(t) and Q(t)) is performed on 2 carrier signals which are orthogonal to each other with a period of 4T, i.e. $A\cos(\pi/2T)$ and $A\sin(\pi/2T)$. The obtained signal is modulated with orthogonal carrier signals $\cos(2\pi f_c t)$ and $\sin(2\pi f_c t)$.

$$s(t) = AI(t)\cos(\frac{\pi t}{2T})\cos(2\pi f_c t)$$
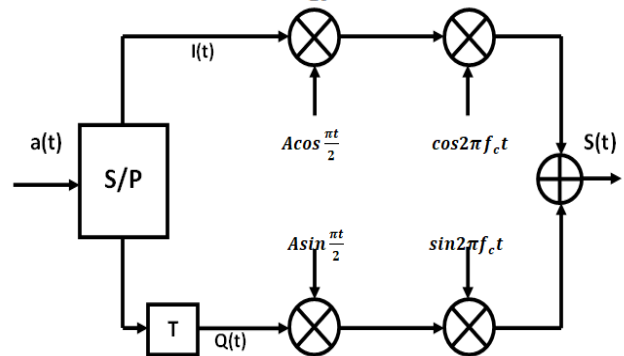$$+ AQ(t)\sin(\frac{\pi t}{2T})\sin(2\pi f_c t) \quad (10)$$

Fig. 3: Block diagram of MSK Modulator

IV . SIMULATION RESULTS

The description of implementing different digital modulation techniques in VHDL is followed in detail. The simulation results were observed in ISim.

In a Conventional QPSK modulator, a 2 bit signal is given as input and corresponding output is observed in Fig. 4.
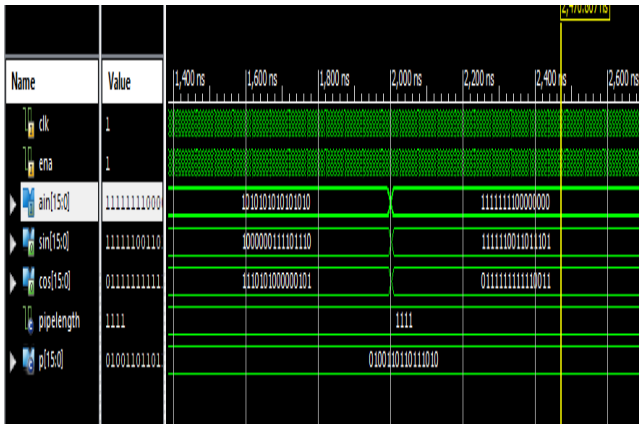
Fig. 4: Simulation Results for Conventional QPSK Modulated Signal

For a CORDIC based QPSK modulator, output is obtained with respect to an input which has stream of bits as shown in Fig. 5 whereas in MSK modulator, three inputs are applied. One is input bit stream and other two inputs are two counters namely K and D counters. In correspondence to different K and D input combinations different output signals are obtained as in Fig. 6.
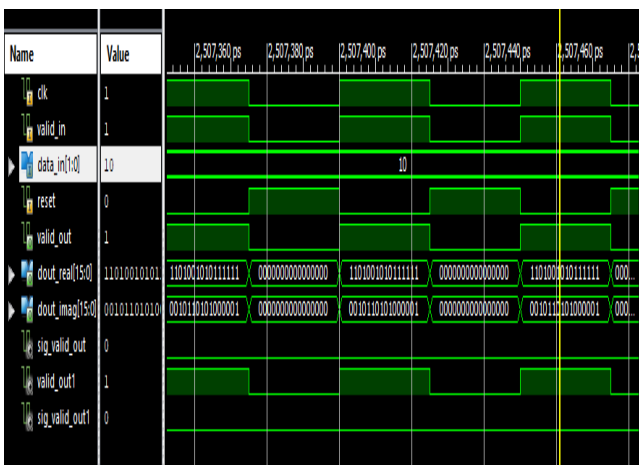

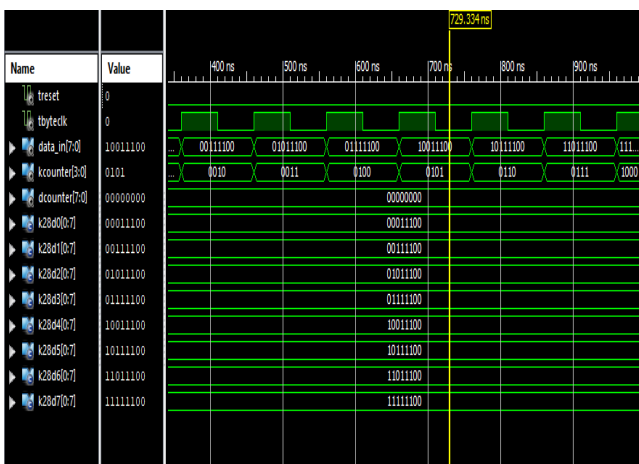Fig. 5: Simulation Results for CORDIC based QPSK Modulated Signal

Fig. 6: Simulation Results for MSK Modulated Signal

V . PERFORMANCE ANALYSIS

The performance of any device is explored by making use of different parameters such as area, delay, power and memory consumed. The performance results of the QPSK, CORDIC based QPSK and MSK modulators in terms of area and time consumed is overviewed with the assistance of design summary generated by Xilinx ISE software.

A. Area Analysis

The area is observed in Design Summary. For Conventional QPSK modulator, area utilized is 21% whereas in the case of CORDIC based QPSK modulator, it is known that area has been reduced to 16%.

In MSK modulator, area is further reduced to a greater extent i.e. 3% making it more efficient compared to other modulation techniques.

B. Time Analysis

The overall time taken to perform the process of modulation techniques is expressed in terms of delay which is shown in Synthesis Report.

From the Synthesis Report, MSK Modulator has very less delay i.e. 3.793ns when compared to Conventional QPSK and CORDIC based QPSK modulators.

Table II: Performance Results of the three Implementations

Implementation	Area	Delay
Conventional QPSK Modulator	21%	4.040ns
CORDIC based QPSK Modulator	16%	4.040ns
MSK Modulator	3%	3.793ns

VI . CONCLUSION

The results of enactment of these modulators in VHDL and the overall analysis demonstrate that the Minimum Shift Keying Modulator offered the finest outcomes in consumption of area and time when compared to the Conventional QPSK Modulator and CORDIC based QPSK Modulator.

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