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Implementation of DQPSK based Transmitter on digital signal processor

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Abstract: In recent times, the implementation of digital system on short-scale embedded platform is gaining interest of research community. However, the absence of implementation strategy is turning out to be a bottleneck. This paper presents a methodology for digital signal processor (DSP) based implementation of communication system with Differential Quadrature Phase Shift Keying (D-QPSK) as band-pass modulation scheme. Most of the functional blocks of standard transmitter are implemented including signal encoding, baseband pulse shaping, and modulation. The symbols are transmitted over a wired channel in the presence of noise. For encoding the input data, Non-return-to-zero encoding scheme is implemented and for pulse shaping, raised cosine pulse shape is implemented. An optimized strategy to implement basic blocks of communication system using embedded hardware is also presented. The transmitter is finally implemented on a commercial Digital Signal Processor (DSP). Results have shown that the DQPSK based transmitter can be implemented on short-scale platforms such as DSP systems.

Keywords: Communication system design, QPSK modulation, DSP kit.

1. Introduction

Digital communication systems are becoming increasingly attractive because of the ever growing demand of data communication [1]. In addition, digital transmission offers data processing options and flexibilities which were not originally available in traditional analog communication systems [2]. The principal feature of digital communication system (DCS) is that during a finite interval of time, it sends a waveform from a finite set of possible waveforms, in contrast to an analog communication system, which sends a waveform from an infinite variety of waveform shapes with theoretically infinite resolution. In a DCS, the objective at the receiver is not to reproduce the transmitted waveform with precision; instead, the objective is to determine from a noise-perturbed signal that which waveform from was transmitted from a set of finite waveforms. Modern digital systems utilize both spectral and temporal features [3, 4]. Modern communication system should be bandwidth efficient as bandwidth is turning out to be a scarce resource [5]. For digital transmitter design, several modulation schemes exist such as Amplitude Shift Keying (ASK), Phase Shift Keying (PSK), and Quadrature Amplitude Modulation (QAM) scheme.

The most fundamental digital modulation techniques are based on keying(switching), and can be summarized as:

- In the case of PSK (phase-shift keying), a finite number of phases are used.
- In the case of FSK (frequency-shift keying), a finite number of frequencies are used.
- In the case of ASK (amplitude-shift keying), a finite number of amplitudes are used.

PSK communication system is widely being used in many applications such as vehicular images-sensor communication system [6], optical camera

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communication system [7], and underwater communication systems [8]. In this study, we used Quadrature-PSK (4-PSK) as a modulation scheme at the transmitter.

For real-time implementation, several platforms exist such as Software Defined Radio (SDR), Field programmable Gate Array (FPGA) systems, and Digital Signal Processors (DSP). Several comparative studies exist such as [9] however, the dominance of these platforms on one-another is still application depended. For this study, we used DSP platform for real-time implementation. Rest of the paper is organized as follow: Section 2 describes the system overview, section 3 discusses the experimental setup and results and finally conclusion is stated in section

2. System overview

As described in figure 1, the conventional communication system mainly comprises mainly of:

- Transmitter
- Receiver
- Channel/transmission medium.

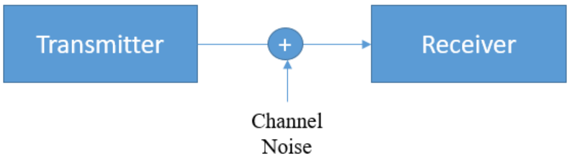

Figure 1: Conventional communication system.

Figure 2. shows the complete overview of implemented communication system. First of all, the incoming bit stream (data source) is fed as an input to DSP kit. Then, first DSP kit serves as a transmitter where the data is modulated and sent over wired channel. Second DSP kit acts as a receiver where data is decoded to recover the transmitted bit-stream. Since the data is travelling from computer 1 to computer 2, we call the first computer as data source and the second one as the data sink. The transmission channel between the transmitter and receiver is analog wired channel.

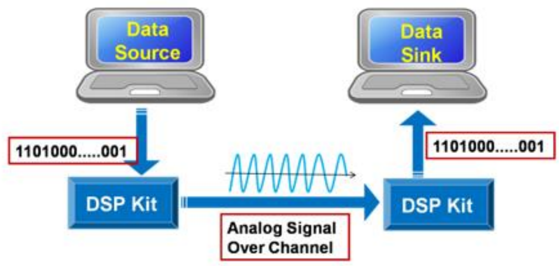

Figure 2: Conventional communication system.

2.1 Digital communication system

As shown in figure 3, a typical communication system has the following modules:

- Sampling and Quantization
- Channel Encoder/ Decoder
- Pulse Shaping
- Modulator/ Demodulator

The function of the A/D converter is to convert analog signal to digital signal. If the source generates digital data, then A/D converter is not required. If the source is analog, then in order to convert it in digital form we have to use an A/D converter. channel encoder eliminates the redundancy in the source data. Transmitting a square pulse requires a lot of bandwidth because the frequency response of a square wave is of infinite duration. This causes inter-symbol interference generally known as ISI. To avoid inter-symbol interference appropriate pulse shaping technique is needed. In this study we used raised cosine pulse shaping as it significantly reduces the ISI factor

Raised cosine pulse is widely used in modern communication systems. The magnitude spectrum of raised cosine spectrum is given as follows.

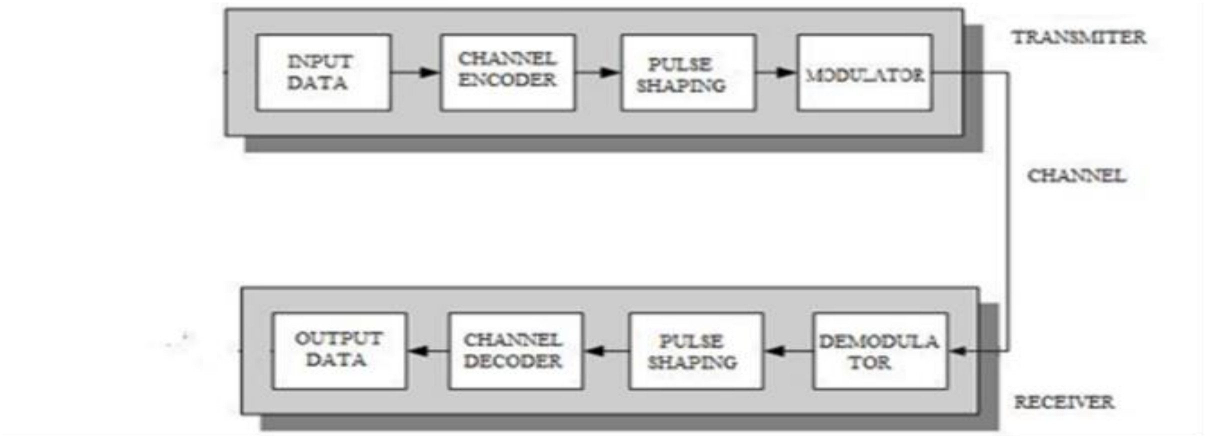

Figure 6: Conventional communication system

$$P(f) = \frac{W\,[1+\cos(\pi f/2W)]}{4}, \qquad 0< |f| <2W \qquad (1)$$

$$0 \qquad |f| \geq 2W$$

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Digital Data from the pulse shaping filter is modulated using the Differential Quadrature Phase Shift Keying (DQPSK) modulation scheme at the Transmitter end. Even and odd channel Differentially encoded bits are convolved with root raised cosine filter and then multiplied with the orthogonal carrier particularly referred to as I-channel (In-phase channel) with carrier cos(2πfct) and the other channel commonly referred to as Q-channel (Quadrature channel) with carrier sin(2πfct). Then both the parallel data streams are added. This process is explained in figure 4. As explained above, first row of the figure shows I-Channel of the modulated signal, second row show Q-channel of modulated signal. Finally, the modulated signals are added and represented in 3rd row to get final QPSK modulated signal which is ready to be transmitted.

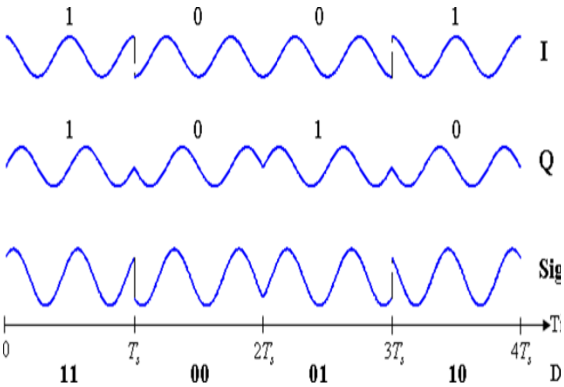


Figure 4: transmitted symbols and their shapes

The resultant signal is ready to be transmitted which is Differential Quadrature Phase Shift Keying (DQPSK) modulated signal.

The implemented DQPSK signal can be defined as:

$$Si(t) = \frac{\sqrt{2E}}{T} \cos\left[2\pi f c t + (2i-1)\frac{\pi}{4}\right.$$

$$0 \leq t \leq T \qquad (2)$$

Where i= 1,2,3,4, E is the transmitted energy per symbol and T is the symbol duration. The carrier frequency fc equals nc/T for some fixed integer nc. The four transmitted signals are shown in figure 4. This is called the quadrature form of the modulation equation. The two signals are orthogonal to each other. The modulating signal can be seen as a vector with I and Q as its x and y components. All the resultant symbols, their mathematical signal and waveform is shown in figure 5. As represented in figure 5, four transmitted symbols represented by s1, s2 s3, and s4 have respective phase angle of 45, 135, 225, and 315 degrees respectively. From s1 to s4 the transmitted symbols are 11,01,00,10. A phase shift of pi/4 can be observed between two consecutive symbols.

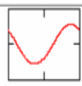
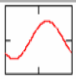
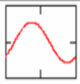
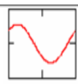
Symbol	Bits	S(t)	Phase, (Deg.)	Mod. Signal At fc	I	Q
S1	00	$\sqrt{\frac{2E_s}{T}}\cos(2\pi f_c t+\pi/4)$	45°		1	1
S2	01	$\sqrt{\frac{2E_s}{T}}\cos(2\pi f_c t+3\pi/4)$	135°		-1	1
S3	11	$\sqrt{\frac{2E_s}{T}}\cos(2\pi f_c t+5\pi/4)$	225°		-1	-1
S4	10	$\sqrt{\frac{2E_s}{T}}\cos(2\pi f_c t+7\pi/4)$	315°		1	-1

Figure 5: Transmitted symbols and their shapes

2.2 Implemented Transmitter.

The important goal in the design of digital communication system is low probability of error and effective utilization of channel bandwidth. One of the bandwidth conserving modulation scheme is Quadrature Phase Shift Keying.

In Quadrature Phase Shift Keying, information carried by the transmitted signal is contained in the phase. In particular, the phase of the integrated block diagram of implemented transmitter is shown in figure 6. Here, De-multiplexer block converts the incoming serial data streams into two parallel streams. It separates the even and odd data bits. And makes parallel odd and even bits' data streams. Symbol information is encoded as the phase change from one symbol period to the next rather than as an absolute phase. Data stream is in the form of binary zero's and one's. Binary NRZ (Non-Return to Zero) encoder encodes the bits to +1 and -1. For binary zero encoder value is -1 and for binary one its value is +1. After pulse shaping, even and odd channel signals are multiplied with the orthogonal carrier's sine (2πfct) and cos(2πfct). This signal is then converted into analog form which is now ready to be transmitted over the channel. Here, the physical medium between the transmitter and receiver is considered as the channel. In our case, to better

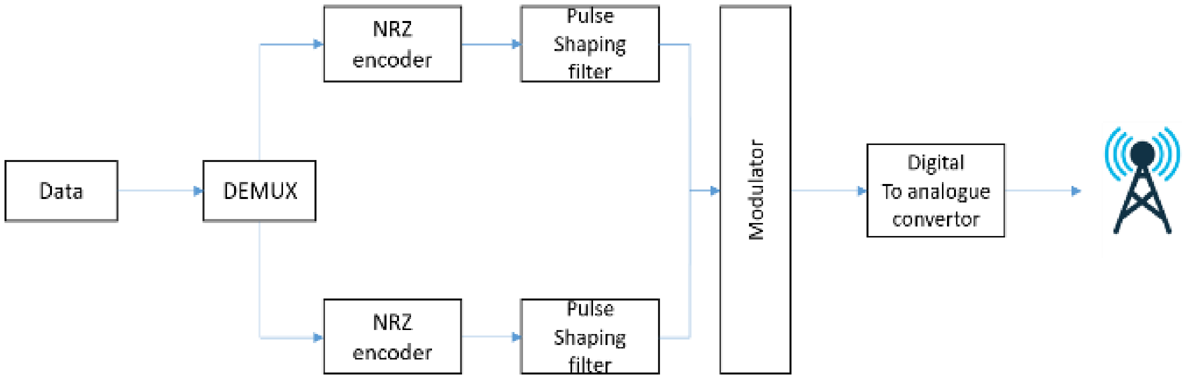


Figure 6: implemented transmitter block diagram

source Device Interface Technology that is used to serve the interest of simplicity, we used wired (AWGN) channel.

3. Experimental setup and results

In this study, we used TMS320C6713 DSP kit from Texas instrument, USA. It is a complete platform comprising of a DSP processor, SDRAM, Flasram, Codec and digital to analog conversion system. The main board is shown in figure 7.

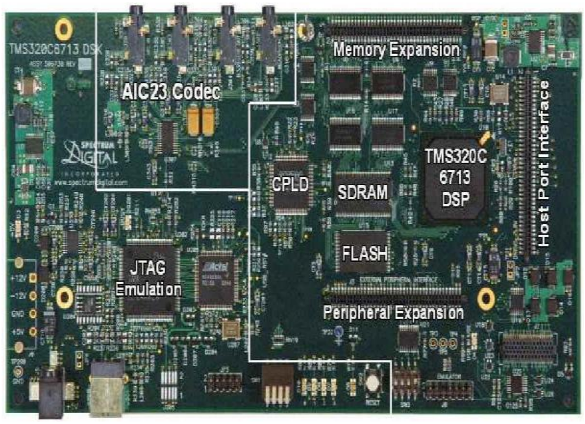


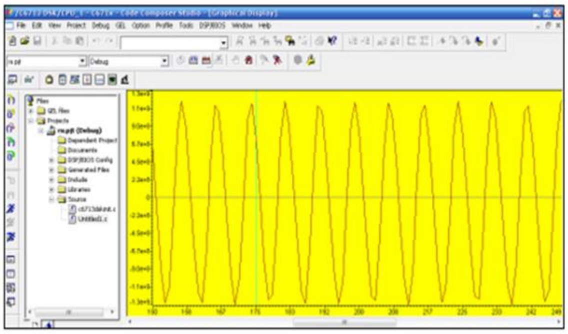
Figure 7: Main board of TMS320C6713 DSP processor.

Table 1 show the parameters used in experimental setup. As shown in table 1, carrier frequency is 6 times less than the sampling frequency. In addition to that the used Root-raised-cosine was of the 73rd order.

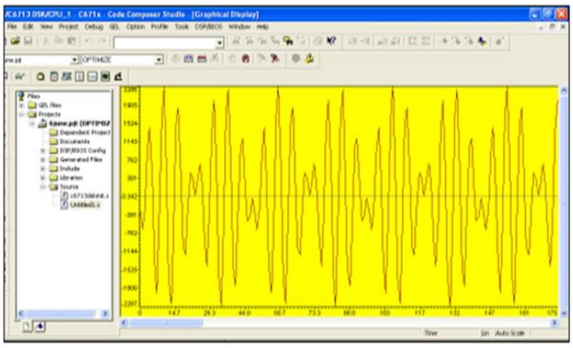
Property	Value
Carrier frequency	16 kHz
Sampling frequency	96 kHz
Bit rate	8 K bits per second
Symbol time	1
Order of pulse shaping filter	73
Filter name	Root raised cosine
Cut-off	½
Programming platform	C language

Table 1: Design parameters

Next, figure 7 presents the simulation results of the transmitter. Here, figure 8(a) represents the transmitted signal with all ones. On the other hand, in order to show the phase shift, figure 8(b) represents the transmitted signal comprising of series of '00 11 00 11' bit streams. The expected phase shift can be easily observed in figure 8(b).



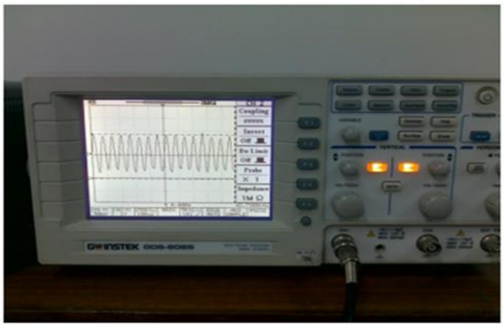
(a)



(b)

Figure 8: figure 8(a) The transmitted signal with all 1's as data stream (b) transmitted signal against the bit stream comprising of bits 00 11 00 11....

For further verification, the DSP kit was connected to an external oscilloscope. Figure 9 represents the results for same bit stream on an external oscilloscope. Figure 9 further suggests and verifies that the algorithm is working as perfect in real-time as well.



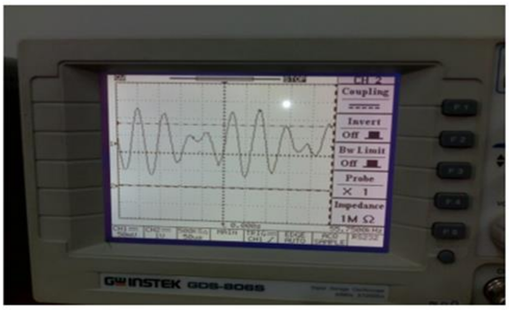


Figure 9: Real-time demonstration with an external oscilloscope. figure 9(a) The transmitted signal with all 1's as data stream (b) transmitted signal against the bit stream comprising of bits 00 11 00 11....

4. Conclusion and further work

We implemented a real-time version of DQPSK based communication system on DSP kits. The transmitter was implemented. All the basic blocks of a standard communication system were implemented. Convincing results have been found and we can conclude that the DQPS based communication system can be implemented on low-cost DSP kits such as TMS320C6713. In future we are aiming to design receiver as well. later a fully integrated transmitter and receiver pair will be implemented.

Author Contributions: S.A. Designed the experiment and the algorithm, S.W. tested the optimized real-time version of the sub-blocks, T.S. carried out experiments, W.K. supervised the overall research work.

Conflicts of Interest: The authors declare no conflict of interest.

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