Performance Analysis of DQPSK Modulated Radio-Over-Fiber System based on NRZ Modulation Format

Shelly Singla
Guru Jambheshwar University of Science and Technology, Hisar

Sandeep K Arya
Guru Jambheshwar University of Science and Technology, Hisar

ABSTRACT

The objective of this paper is to implement a Differential Quadrature Phase Shift Keying (DQPSK) modulated Radio signal over Fiber (RoF) transmission system. The DQPSK modulator in RF domain is implemented at the transmitting end and at the receiving end, non-coherent differential detection is used to demodulate the RF signal. The modulation scheme used in the optical domain is the standard Intensity Modulation with Direct Detection (IM-DD). Bit-error-rate (BER) has been investigated for non return to zero (NRZ) modulation format. Eye diagram have also been obtained. DQPSK with non return to zero format has been found to be an efficient format for an error free RoF transmission system.

Keywords:
RoF, DQPSK, NRZ, BER

1. INTRODUCTION

Radio-over-fiber (RoF) techniques which combines high capacity of optical fiber and mobility of cellular radio systems has received much attention as a key technology for high-speed next-generation access networks due to the well known advantages such as ultrahigh bandwidth, avoidance of frequency congestion, low transmission loss, and so on [1], [2]. In such hybrid optical-wireless systems, generation and transmission of high-speed signals in a simple and cost-efficient way is vital to real networks [3]–[5]. Many advanced modulation formats which carry several data bits in a single symbol, including amplitude shift keying (ASK), phase shift keying (PSK), quadrature phase shift keying (QPSK), differential quadrature phase shift keying (DQPSK) and quadrature amplitude modulation (QAM), have been investigated over the past ten years for increasing spectral efficiency while reducing symbol rate [6]. Among these efficient formats, DQPSK and QAM are particularly attractive for its relatively low signal-to-noise ratio (SNR) requirement compared with others when having the same bits per symbol [7].

In this paper, the performance evaluation has been done for DQPSK system for NRZ modulation format. Eye diagram and BER have also been investigated.

2. MODELLING

The schematic layout of the DQPSK modulated radio-over-fiber system is shown in Fig 1. The NRZ rectangular driver gives an electrical output signal which can assume one of the two electrical levels depending on the transmitted bit. When a "1" is fed into the driver, the output signal is at the high level during the entire bit time. When a "0" is fed into the driver, the output signal is at the low level during the entire bit time.

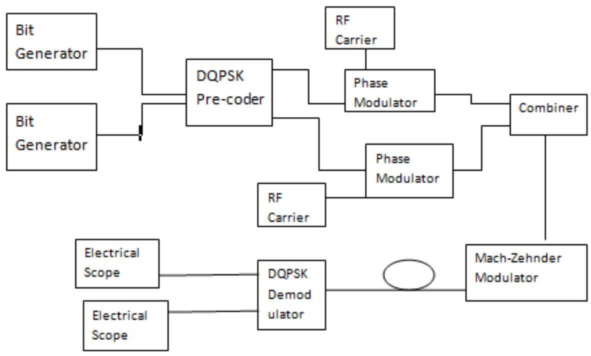


Figure 1: Schematic layout for DQPSK transmission in RoF system

The DQPSK generation requires that I and Q signals be differentially encoded before being phase modulated in the RF domain. This differential encoding of the I and Q signals is implemented through a component called the DQPSK Precoder, whose output I_k, Q_k at any stage depends upon the current state inputs a_k, b_k and previous state outputs I_{k-1}, Q_{k-1} according to the relation as:

$$I_k = (a_k \oplus b_k).(\overline{a_k \oplus I_{k-1}}) + (a_k \oplus b_k).(b_k \oplus Q_{k-1}) \quad (1)$$

$$Q_k = (a_k \oplus b_k).(\overline{b_k \oplus Q_{k-1}}) + (a_k \oplus b_k).(a_k \oplus I_{k-1}) \quad (2)$$

The output of this DQPSK precoder component thus depends on its current state input bits and the previous state output bits, which is then sent for the conventional QPSK modulation with an RF carrier, thus producing the DQPSK modulated RF signal. The block diagram of the logic implemented inside the precoder block is shown in figure 2 below:

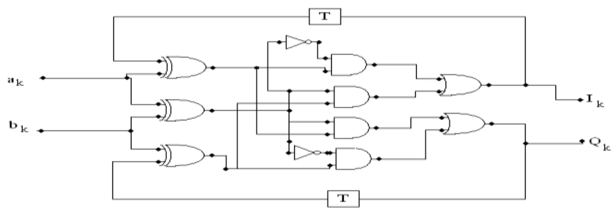


Figure 2: Precoder design for generating *I* & *Q* bit sequences

The pre-coded I and Q bit sequences are then used to phase modulate two RF carrier components having a phase difference of 90° at a signal frequency of 1.28 GHz. The combined signal is then intensity modulated with a laser output and transmitted over a single mode fiber of length 10 kms. At the non-coherent receiver, the incoming DQPSK signal at the kth symbol period can be represented as:

$$R_k(t) = I'_k \cos(wt) + Q'_k \sin(wt) \qquad (3)$$

where I'_k and Q'_k can take any of the values between $\pm(1/\sqrt{2})$ and $\pm(1/\sqrt{2})$ respectively.

In the DQPSK demodulator circuit, the I and Q components are recovered by multiplying the received signal by its bit delayed, phase-shifted version and filtereing out the high-frequency components.

Let the bit-delayed arm of the differential demodulator introduce a phase-shift of Ø radians. Then, following equation (3) above, the inputs to the multiplier can be represented as:

$$R_k(t) = A * Cos(\omega t + m * pi/4)$$

$$R'_{k-1}(t) = A * Cos(\omega t + n * pi/4 + Ø)$$

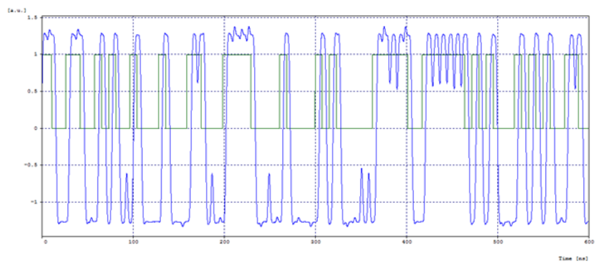
Receiver current may be given as:

$$I_r(t) = A2 * Cos(\omega t + m * pi/4) * Cos(\omega t + n * pi/4 + Ø)$$

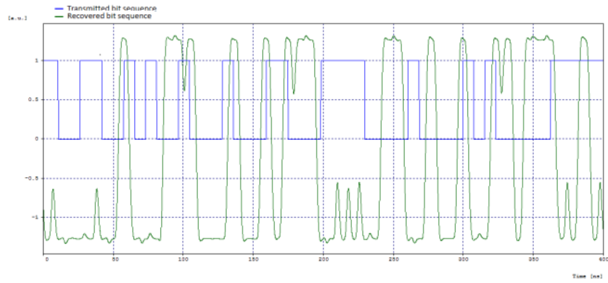
$$I_r(t) = (A2/2) * [Cos\{2\omega t + (m+n) * pi/4 + Ø\} + Cos\{(m-n) * pi/4 - Ø\}]$$

where m, n can take any of the four values ±1, ±3 each. The high-frequency component is filtered out by the low pass filter (LPF), leaving just the offset term $Cos\{(m-n) * pi/4 - Ø\}$. To map this filtered output $I_r(t)$ to the transmitted in-phase component I(t), the value of this cosine term must have only two discrete possibilities for all combinations of the values for m & n between $\pm1, \pm3$. It is easy to see with some trigonometric calculations that only the values of '$Ø = \pm pi/4$' satisfy this condition. Further more, from the precoder circuit, it can be deduced that the value of φ = -pi/4 maps the filtered output $I_r(t)$ to the input in-phase component I(t). Similar argument shows that a value of φ = +pi/4 maps the output of the quadrature arm of the demodulator to the input quadrature component Q(t). Hence, the phase-shift values used for the in-phase recovery and quadrature recovery circuits at the demodulator are -pi/4 and +pi/4 respectively.

We plot in Figure 4(a), the recovered in-phase component $I_r(t)$ along with its corresponding transmitted sequence $I(t)$ for non return to zero modulation format for the first few bits. Similarly the recovered Quadrature component $Q_r(t)$ with that of the corresponding transmitted sequence $Q(t)$ for non return to zero modulation format is also shown in Fig 4(b). It can be seen from Fig 4 (a) and (b) that the demodulated bit sequences match with that of the transmitted sequences bit-by-bit.



(a)

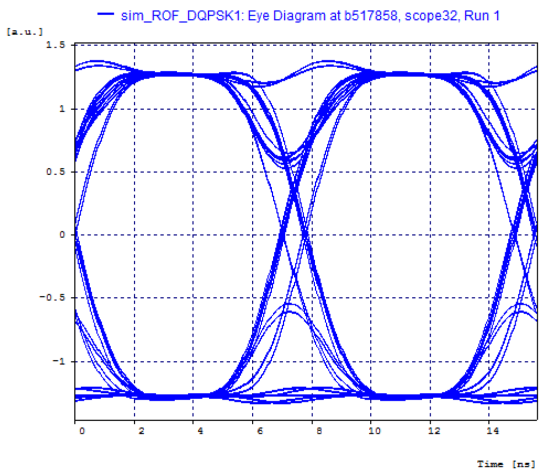


(b)

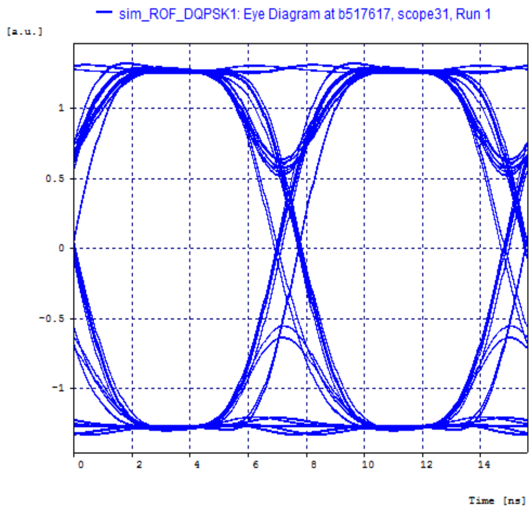
Figure 4: Received and transmitted bit sequences for NRZ modulation format a) In phase sequences (b) Quadrature phase sequences

Figure 5 (a) and (b) show the simulated eye diagrams after fiber transmission for NRZ format sequences for in-phase and quadrature components. The Q-factor is found to be -40 dB, eye opening is 2.53559 [a.u] for in phase and quadrature phase eye patterns while jitter is found to be 0.846113 ns for in phase and 1.04334 ns for quadrature phase component.

The bit error rate (BER) value for the received components is about 1E-40 for NRZ format sequence which corresponds to an error-free transmission.



(a)



(b)

Figure 5: The eye-diagram for the demodulated NRZ format sequences (a) in-phase components (b) quadrature components.

3. CONCLUSION

The DQPSK modulator in RF domain is implemented at the transmitting end and at the receiving end, non-coherent differential detection is used to demodulate the RF signal. The transmitted and recovered bit sequences are found in phase with each other. Bit-error-rate (BER) has also been found in the range ensuring reliable communication. DQPSK with non return to zero formats has been found to be an efficient format for an error free RoF transmission system.

4. REFERENCES

[1] T. Kurniawan, A. Nirmalathas, C. Lim, D. Novak, and R.Waterhouse, Performance analysis of optimized millimeter-wave fiber radio links, *IEEE Trans. Microw. Theory Tech.*, 2, 54, (2006).

[2] X. Zhang, B. Liu, J. Yao, K. Wu, and R. Kashyap, “A novel millimeter-wave-band radio-over-fiber system with dense wavelength-division multiplexing bus architecture,” *IEEE Trans. Microw. Theory Tech.*, 2, 54, (2006).

[3] P. Candelas, J. Fuster, J. Marti, and J. Roig, “Optically generated electrical-modulation formats in digital-microwave link application,” *J. Lightw. Technol.*, 2, 21, (2003).

[4] R. Sambaraju, M. A. Piqueras, V. Polo, J. L. Corral, and J. Marti, “Generation of multi-gigabit-per-second MQAM/MPSK-modulated millimeter-wave carriers employing photonic vector modulator technology,” *J. Lightw. Technol.*, 11, 25, (2007).

[5] M. A. Piqueras, B. Vidal, J. L. Corral, V. Polo, A. Martinez, and J.Marti, “Direct photonic generation of electrical vector modulations at microwave/millimeter-wave frequencies,” *IEEE Photon. Technol. Lett.*, 9, 17, (2005).

[6] C.Weng, Y. Lin, and W.Way, “Radio-on-fiber 16-QAM, 100 km transmission ar 5 Gb/s using DSB-SC transmitter and remote heterodyne detection,” *J. Lightw. Technol.*, 6, 26, (2008).

[7] V. Urick, J. Qiu, and F. Bucholtz, “Wide-band QAM-over-fiber using phase modulation and interferometric demodulation,” *IEEE Photon. Technol. Lett.*, 10, 16, (2004).