Performance improvement of Quadrature Amplitude Modulation QAM-based transmission using convolution code

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ABSTRACT

In this paper, a simulation-based implementation was used to improve the performance of the quadrature amplitude modulation QAM-based transmissions using convolution code. The simulation-based implementation was performed using SIMULINK software. In this implementation, a portion of data was randomly generated, modulated using 64-QAM, and sent through an Additive White Gaussian Noise AWGN channel and then being demodulated, at the receiving side. Another portion of data was randomly generated, encoded using convolution code with 2/3 code rate before being modulated using 64-QAM, and then sent through the same AWGN channel before being demodulated, and decoded at the receiving side. Comparing the two cases of transmissions, results revealed that there is a significant improvement of performance in the latter case where convolution code was used (i.e. a bit-error-rate BER decrease) as the energy per bit-to-noise power spectral density Eb/No ratio goes beyond 15 dB.

Keywords *- Digital-to-analog transmission, quadrature amplitude modulation QAM, coding schemes, block code, convolution code*

I. INTRODUCTION

A variety of analog transmission schemes also referred to as digital-to-analog transmission schemes in which sinusoidal signals are employed to carry information, such as Amplitude Shift Keying ASK, Frequency Shift Keying FSK, and Phase Shift Keying FSK were traditionally used [1]. In theses schemes, the amplitude, frequency or phase of a sinusoidal carrier is modulated to carry information. While PSK was considered as the most efficient technology due to its less sensitivity to noise, it is limited by its ability of equipment to distinguish small differences in phase, which leads to limit its potential bit rate [2]. A more efficient and alternative scheme is Quadrature Amplitude Modulation (QAM). In QAM, both the amplitude and phase of the carrier is modulated. This dual modulation characteristics gives the ability to staff as twice as much information into the transmission channel while maintenance a specific bandwidth [3] [4] [5]. Figure 1 shows a schematic diagram of a basic digital-to-analog transmission scheme.

It is desirable for any communication systems to be able

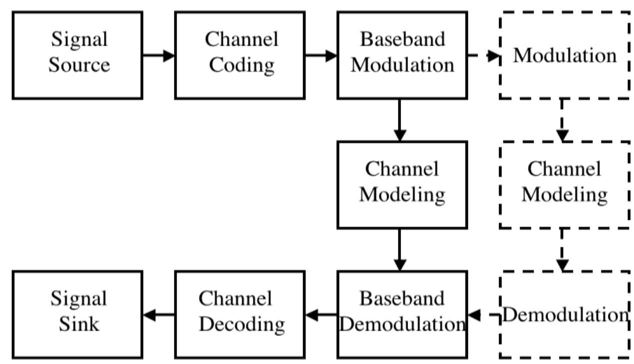

Figure 1, Basic digital-to-analog transmission scheme

to transfer information with acceptable accuracy, i.e. a communication system must fulfill a specific criterion which guarantees that the information received are almost identical to information transmitted. To do so, coding schemes were developed by which the bit-error-rate BER is minimized. Coding schemes can be classified into two categories; block codes and convolution codes [6] [7] [8]. In both categories, a redundant bits are added to the original information which helps detecting and correcting of errors and thus leads to decrease the bit-error-rate BER. Unlike the classic block codes, which are generally represented by a time-variant trellis and therefore are typically hard-decision decoded, the convolution code is maximum-likelihood soft-decision decoded with reasonable complexity. Convolution codes are often characterized by the base code rate and the depth (or memory) of the encoder [n,k,K]. The base code rate is typically given as n/k, where n is the input data rate and k is the output symbol rate. The depth is often called the constraint length (K), where the output is a function of the current input as well as the previous K-1 inputs. The depth may also be given as the number of memory elements v in the polynomial or the maximum possible number of states of the encoder (typically 2v). The code rate of a convolutional code is commonly modified via symbol puncturing. For example, a convolutional code with a mother code rate n/k = 1/2 may be punctured to a higher rate of, for example, 2/3, 3/4, 5/6, or 7/8. In this paper, a simulation-based implementation was used to improve the performance of the QAM-based transmissions using convolution code with 2/3 code rate.

II. SIMULATION SETUP

Figure 2 shows the block diagram of our simulation where both, the communication toolbox and communications block set were used for building it.

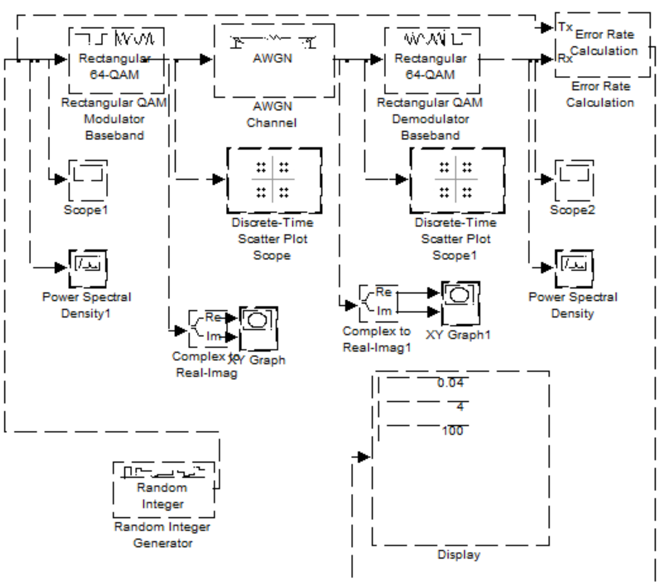

Figure 2, simulation setup

In the simulation setup, a random binary data (a uniformly distributed binary integers [0,1]), which represents the input information, is generated by a random binary generator as shown in Figure 3. A 64-QAM modulator was involved which allows each signal element (sinusoidal waveform) to carry six data element (6 bits). Figure 4 (a) shows the produced 64-QAM where changing in the phase and amplitude of the signal can be seen obviously. Figure 4 (b) shows the corresponding constellation diagram of the produced 64-QAM signal. An additive white Gaussian noise (AWGN) channel is used as a medium of transmission where the only

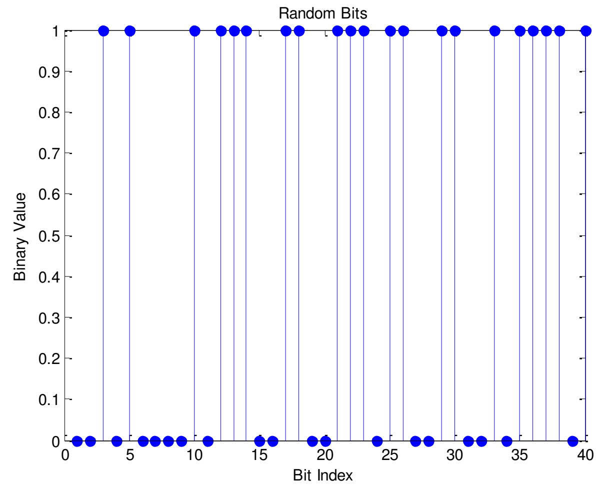

Figure 3, A randomly generated binary data

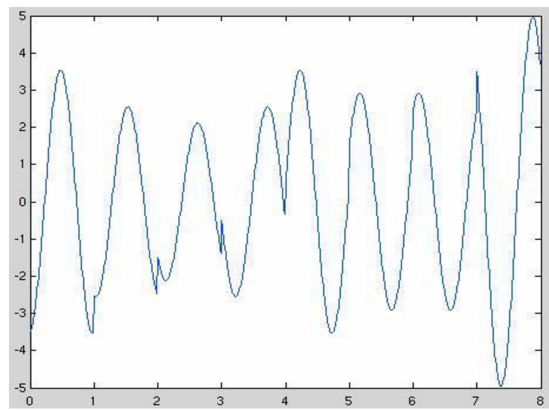

Figure 4 (a) produced 64-QAM signal

impairment affecting the communication is a linear addition of white noise. Figure 5 shows the received 64-QAM signal with Eb/No equals to 10 dB. Figure 6 (a) and (b) show the corresponding constellation diagrams of the received 64-QAM signal where an Eb/No ration equals to 10 dB and 20 dB was considered, respectively. Observing both figures, one can easily note that the effect of noise is quite severe in the first case where a more scattered plot of noisy signal can be obviously seen. The process of extracting the baseband signal (modulating signal) from the bandpass signal (modulated signal) is performed at the receiving side (i.e. demodulation process) by multiplying the received signal with a local sinusoidal wave. A decoder that performs the inverse of the designed 64-QAM channel coder is employed. A convolutional code was employed with 2/3 rate using the code ‘’ code = convenc(source binary data,t) where t equal poly2trellis([5 4,[23 35 0; 0 5 13])’’. In the decoder we use the code ‘’ viterbi , the decoded information = vitdec(binary data after inverse mapping ,t, Traceback length for decoding ,'cont','hard')''.

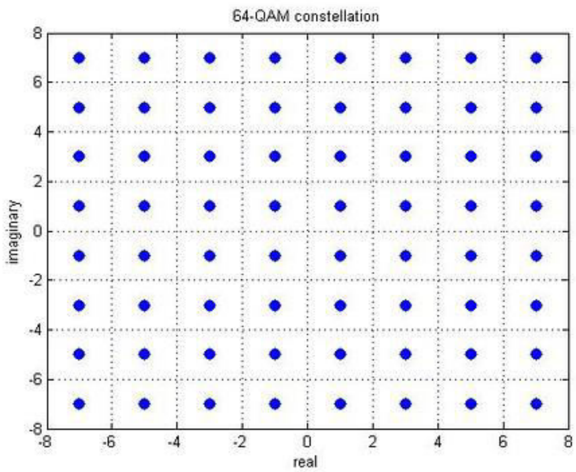

Figure 4 (b) constellation diagram of the produced 64-QAM signal

The codes are very interesting for both Matlab script

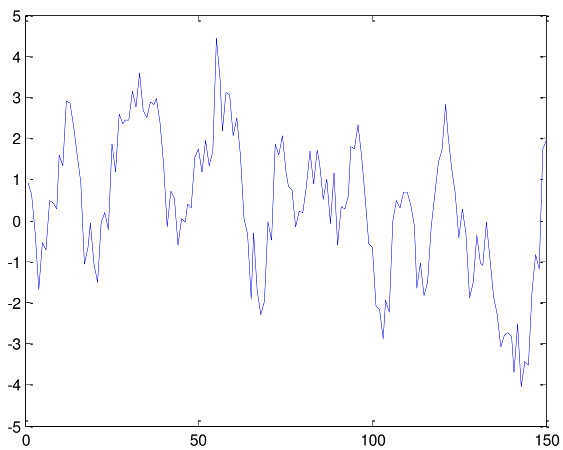

Figure 5. 64-QAM signal during transmission within the AWGN channed with Eb/No =10 dB.

code and Simulink.

III. RESULTS AND DISCUSSION

In this part, we run the simulation that has been prepared in the previous section to compare the performance of the 64-QAM transmission considering two different cases. In the first case, an uncoded 64-QAM signal was considered, whereas a coded 64-QAM signal in which a convolution code with 2/3 rate was considered in the second case. In both cases, the bit-error-rate BER versus the energy per bit-to-noise power spectral density Eb/No was graphically represented. To obtain a quite obvious comparison, we combine the two graphs into a single figure. Figure 7 shows BER versus Eb/No for the coded and uncoded 64-QAM transmissions, where a significant improvement in the performance in the case of coded transmission can be obviously observed as the Eb/No goes beyond 15 dB.

IV. CONCLUSIONS

In this paper, the performance of the QAM-based transmissions was improved by using the convolution code. The improvement was based a simulation implementation. Results confirmed that a significant improvement in the performance (i.e. a dramatic decrease in the BER) can be achieved using the convolution code as the Eb/No ratio goes beyond 15 dB.

REFERENCES

[1] Bernard Sklar, ''*Digital communications: Fundamentals and applications*'', Prentice Hall PTR, Second Edition, 2000.

[2] Behrouz A. Forouzan, ''*Data communications and networking*'', McGraw-Hill, Fourth Edition, 2007

[3] Qinghui Chen, Jing He, Rui Deng, Ming Chen, Lin Chen, ''*FFT-Size Efficient 4096-QAM OFDM for Low-Cost DML-Based IMDD System*'', IEEE Photonics Journal, Volume 8, Number 5, October 2016

[4] Ankita Jain; Pradeep Kumar Krishnamurthy; Pascal Landais; Prince M. Anandarajah, ''*EKF for Joint Mitigation of Phase Noise, Frequency Offset and Nonlinearity in 400 Gb/s PM-16-QAM and 200 Gb/s PM-QPSK Systems*''. IEEE Photonics Journal, Volume 9, Number 1, October 2016

[5] Sunil Kumar Gaire; Saleh Faruque, ''*Performance analysis of orthogonal coded M-ary QAM modulation technique*'', Proceeding of the 51st Annual Conference on Information Sciences and Systems (CISS), pp 1-6, 2017

[6] J. S. Reeve; K. Amarasinghe, ''*A FPGA implementation of a parallel Viterbi decoder for block cyclic and convolution codes*'', Proceeding of IEEE International Conference on Communications, 2004 (IEEE Cat. No.04CH37577)

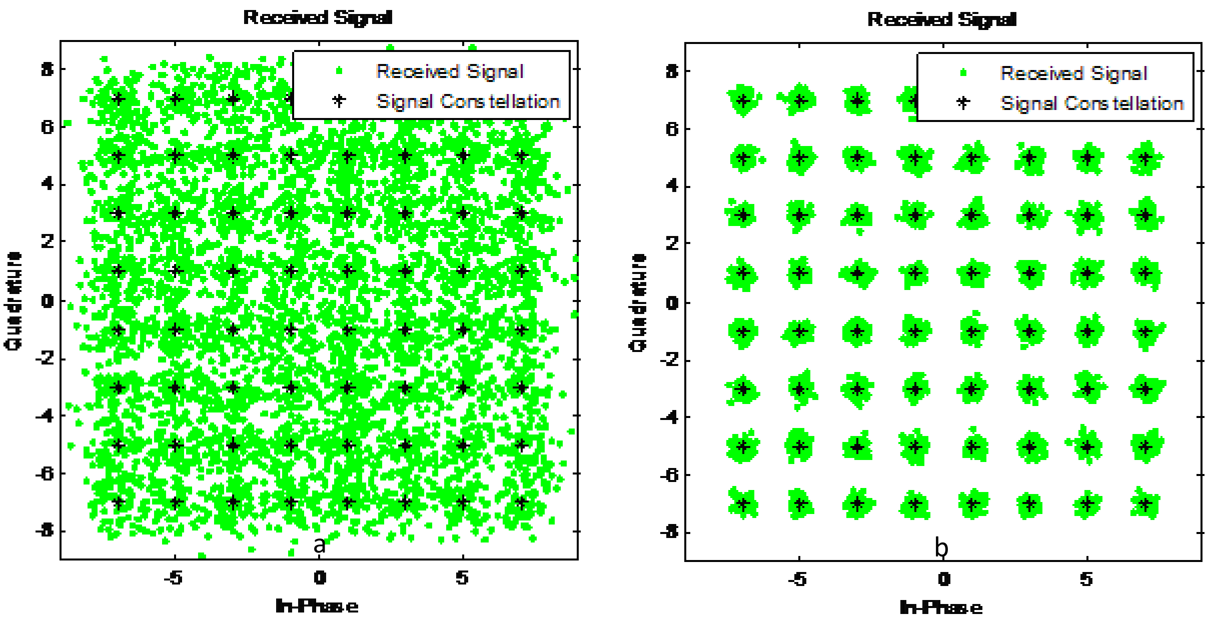

Figure 6 (a) and (b), constellation diagrams of the received 64-QAM signal, (a): Eb/No = 10 dB, (b): Eb/No = 20 dB.

[7] Alexey G. Shapin, ''*Modeling HARQ system with convolution and block codes*'', International School and Seminar on Modern Problems of Nanoelectronics, Micro- and Nanosystem Technologies, pp 65 – 66, 2009

[8] J. Manikandan; M. Manikandan, ''*Performance analysis of various FEC codes for wireless communication*'', Proceeding of the Second International Conference on Current Trends In Engineering and Technology – ICCTET, pp 435 – 440, 2014

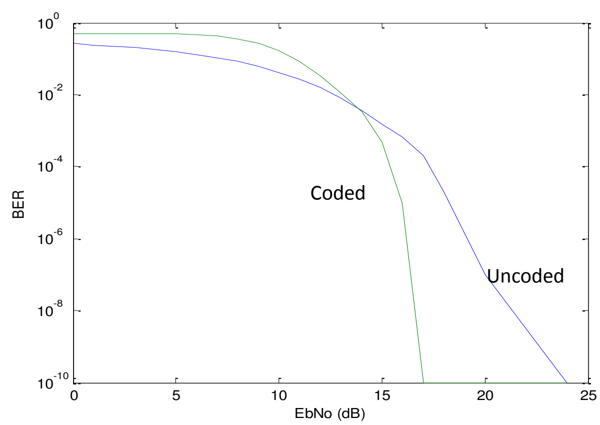

Figure 7, BER vs Eb/No for uncoded and convolutinal coded 64-QAM signal