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AN ALGORITHM FOR AUTOMATIC RECOGNITON OF DIGITAL QAM MODULATIONS

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Abstract: *This paper proposes a new Matlab-developed algorithm for automatic recognition of digital modulations using the constellation of states. Using this technique the automatic distinction between four digital modulation schemes (8-QAM, 16-QAM, 32-QAM and 64-QAM) was made. It has been seen that the efficiency of the algorithm is influenced by the type of modulation, the value of the signal-to-noise ratio and the number of samples. In the case of an AWGN noise channel the simulation results indicated that the value of SNR (signal-to-noise ratio) has a small influence on the recognition rate for lower-order QAM (8-QAM and 16-QAM). The length of the signal may change essentially the recognition rate of this algorithm especially for modulations with a high number of bits per symbol. Consequently, for the 64-QAM modulation in a case of 25dB signal-to-noise ratio the recognition rate is doubled if the sample rate is incresed from 5400 to 80640.*

Keywords: digital modulation, automatic recognition, QAM, constellation of states.

1. Introduction

Over the past few years, a wide range of algorithms for automatic recognition have been developed. The following is a short overview of some published papers in which both digital and analogue modulation is discussed. For example, B.I. Dahap and H.I. Ahmed [1] suggest an algorithm for automatic recognition of analogue modulation to discriminate between several types of modulation: frequency modulation (FM), amplitude modulation (AM), carrier wave (CW), upper side band (USB), lower side band (LSB), double side band (DSB) and combined (AM-FM). The overall recognition of this algorithm is almost 97% when the signal to noise ratio (SNR) is 0 dB.

Y.T. Chan and others [2] proposed an algorithm capable of automatically distinguishing between several types of modulation (AM, FM, DSB, SSB) based on the envelope characteristics of the received signal. This algorithm has an efficiency of approximately 98% for an SNR = 7 dB.

Regarding the automatic recognition of digital modulation, Z. Jin-mei, Wang Hua-kui and others [3] suggest an algorithm based on artificial neuronal network (ANN) technique, with a recognition rate of 98% when SNR = 8 dB. This algorithm can be used to discriminate between eight digital modulations: 2ASK, 4ASK, 2FSK, 4FSK, BPSK, QPSK, 16 QAM and 64 QAM. The artificial neuronal networks have also been used for automatic recognition of digital modulations by Nandi and Azzouz [4]. The automatic distinction between several types of QAM and PSK modulations was also disscused by S. Ghasemi and A. Gangal [5]. These two authors have proposed an algorithm for AMR automatic modulation recognition (AMR) of six types of modulation: 16-QAM, 32-QAM, 64-QAM, BPSK, QPSK and 8-PSK affected by AWGN noise.

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The efficiency of this technique is 100% in case of QAM modulations for a signal-to-noise ratio of -7 dB. Regarding PSK modulations, the recognition rate is 100% for BPSK modulation, 99% for QPSK and 98% for 8-PSK, when the SNR is greater than -2 dB.
This paper focuses on describing a technique for automtic recognition of digital modulations according to the signal constellation of states. Using this algorithm, the automatic distinction between 4 types of QAM modulations (8QAM, 16QAM, 32QAM and 64QAM) is possible. In the first part of the paper it is described the algorithm realized with the Matlab software followed by an analysis referring to the algorithm efficiency. The recognition rate was
analyzed based on two parameters: the signal to noise ratio and number of samples.
The last part of the paper presents a series of conclusions resulting from the analysis performed and the interpretation of the results obtained.

2. Description of the algorithm

The algorithm was implemented using the Matlab simulation environment and proposes an automatic recognition technique for Quadrature Amplitude Modulation (QAM) modulations, based on the signal constellation of states, known as the I-Q representation of the signal.
This technique comprises two main stages:
Stage no. 1: Processing the I and Q coordinates of the received signal and transponding them as a digit of 1 into a square matrix that initially is null. Figure no.1 illustrates this step of the algorithm for a 8QAM modulated signal.

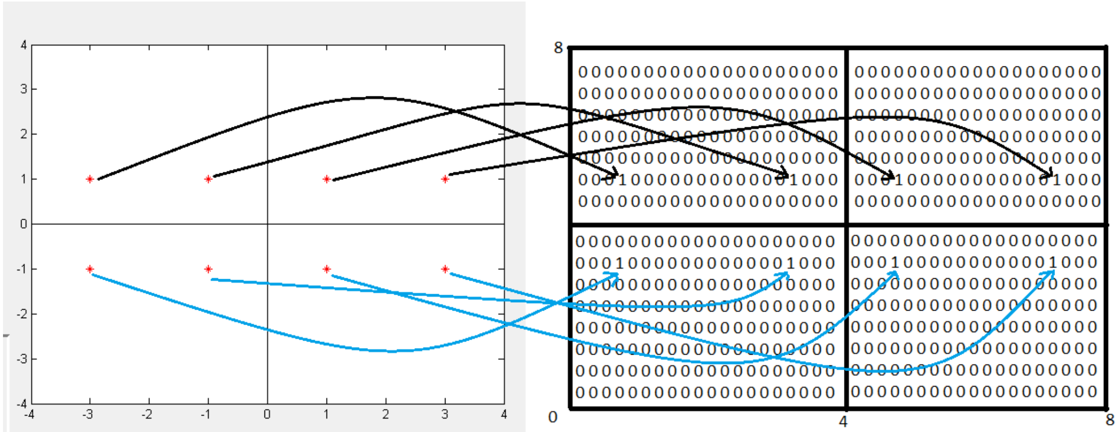

Figure no.1 – Transposing I-Q coordinates into a null matrix

Stage no. 2: From this moment, the result of the algorithm is given by dividing the previous matrix into a number of 64 submatrices and counting the non-null submatrices. For example, for the signal illustrated in Figure no.1, there is a total of 8 non-zero submatrices so the result of the algorithm will be 8QAM modulation.
To improve the efficiency of the algorithm, the number of submatrices in which the initial matrix is splitted is adaptive. In particular, if the algorithm is running and the result is not 64QAM, the algorithm runs again but the matrix will be divided into 32 submatrices. This improves the efficiency of the algorithm and reduces the likelihood of cataloging an element belonging to another submatrix as belonging to an adjacent submatrix.
So far, a brief description of the algorithm has been made, Figure no. 2, showing the totality of the steps the technique described, follows to achieve automatic recognition of the processed signals.

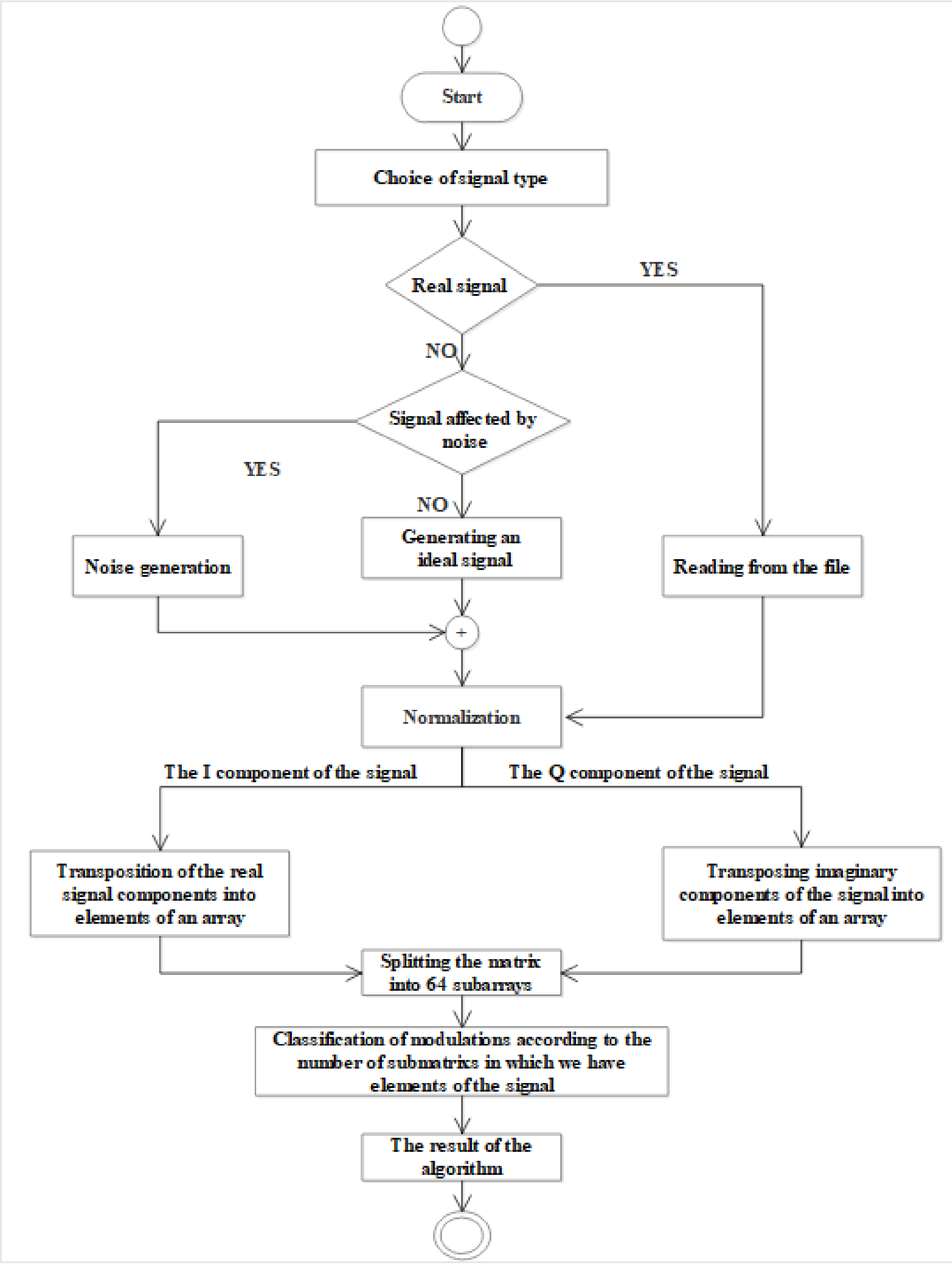

Figure no. 2 - Logical diagram of the algorithm

3. Results and discussions

In this section, the recognition rate of the proposed algorithm was analyzed based on two parameters: the number of samples and the value of the signal-to-noise ratio. In the first part of the analysis it is presented how the efficiency of the algorithm is influenced by the SNR value.

For this, the algorithm was run on a series of signals generated in Matlab with a length of 20160 samples. These signals have subsequently been modulated under several forms of QAM modulation and subjected to AWGN noise.

The results obtained from this first analysis are presented in Table no. 1 illustrated in Figure 3.

Table no.1 – Efficiency of the algorithm based on SNR

Modulation type	Recognition rate for several SNR values [dB]				
	15	**20**	**23**	**25**	**28**
8QAM	30%	70%	100%	100%	100%
16QAM	20%	60%	70%	90%	100%
32QAM	0%	50%	60%	70%	80%
64QAM	0%	10%	20%	50%	50%

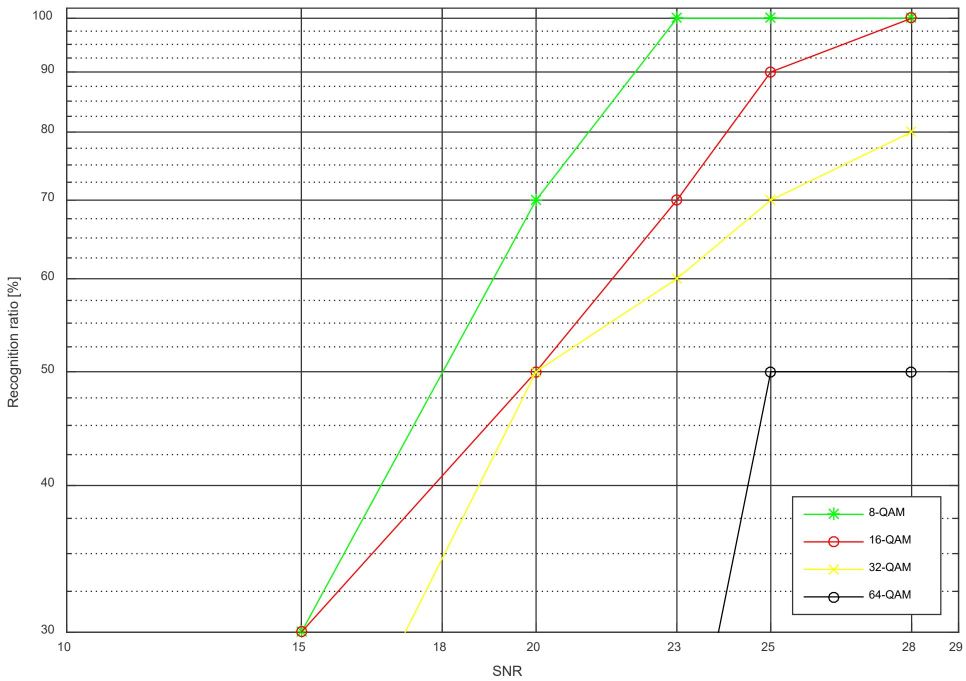

Figure no. 3 – Efficiency of the algorithm based on SNR

It is noted that in the case of 16-QAM modulation, to achieve a 90% recognition rate at a signal length of 20160 samples, a signal-to-noise ratio of 25 dB is required. For the same SNR value, in the case of 32-QAM modulation, the recognition rate of the algorithm was 70%. For the same parameters, the recognition rate of 64 QAM modulation has an efficiency of only 50%. Under these circumstances, we can say that, at the current state of implementation, this algorithm is not very effective in recognizing high order modulations, as in the case of 64QAM. On the other hand, a very good recognition rate is observed for the 8-QAM modulation: 70% for SNR = 20 dB and 100% for signal-to-noise ratio greater than or equal to 23 dB. This is due to the fact that the algorithm is adaptive depending on the type of modulation, thus detecting lower order modulations at smaller SNR values.

The second part of the analysis focused on how the length of the signal influences the efficiency of the algorithm. In this case, a series of signals whit different lengths were generated and after that, subjected to the influence of AWGN noise at an SNR equal to 25 dB. The results obtained are presented in Figure no. 4 and in Table no. 2.

Table no.2 – Efficiency of the algorithm based on the number of samples

Type of modualton	The recognition rate for several lengths of the signals				
	5400	10800	20160	40320	80640
8QAM	100%	100%	100%	100%	100%
16QAM	80%	80%	90%	90%	90%
32QAM	30%	40%	70%	70%	90%
64QAM	40%	40%	50%	70%	80%

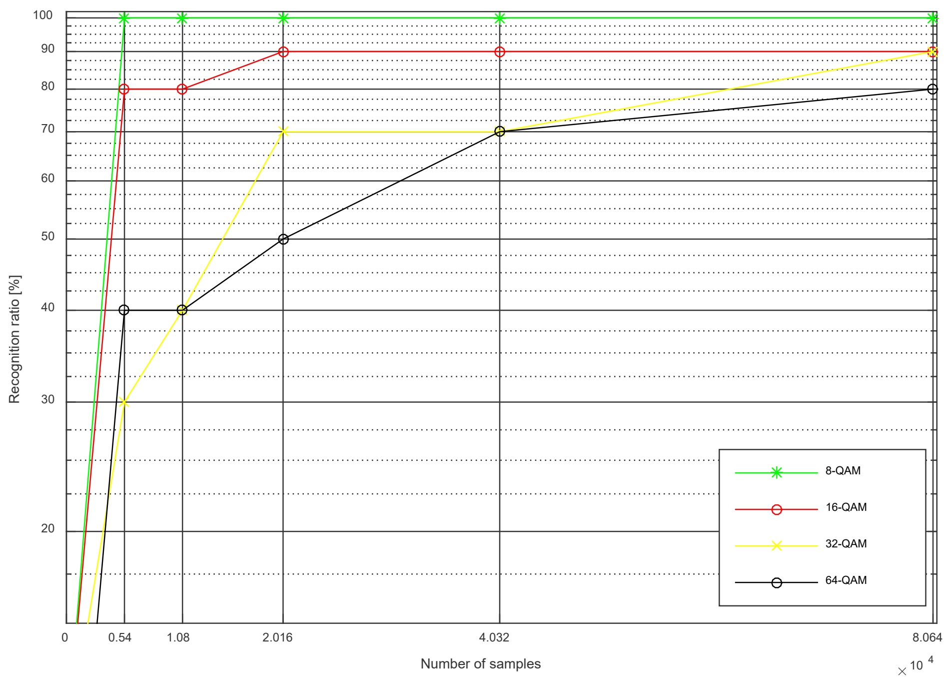

Figure no. 4 – The recognition rate for several lengths of the signals

Note that the major types of modulation whose cognition is influenced by the length of the signal are high order modulation (32 QAM and 64QAM).

In the case of 64-QAM modulation, a significant improvement in the recognition rate is observed with the increase in the number of samples: 80% in the case of a signal with 80640 samples compared to 40% for a signal with a length of 5400 samples. On the other hand, for a 32-QAM modulation, a 30% recognition rate was obtained for a signal with 5400 samples, increasing significantly with increasing number of samples (90% for a signal with 80640 samples).

Regarding the recognition of the 8-QAM modulation, a 100% efficiency is observed for all 5 simulated signal lengths, due to the SNR value (25 dB) for which the algorithm's high efficiency has previously been demonstrated.

4. Conclusions

In this paper, a Matlab-developed method for automatic recognition of QAM digital modulations has been proposed. The technique followed the distinction between different types of modulations based on the constellation of states of the analyzed signal (representation I and Q). Based on the analysis performed and the interpretation of the obtained results, it is observed that the main factors influencing the rate of recognition of the proposed algorithm are: the type of modulation, the number of samples and the signal-to-noise ratio.

Regarding the signal-to-noise ratio, it has been found that the use of this algorithm for recognizing low packing factor modulations (8-QAM, 16QAM) enjoys a much higher efficiency compared to the recognition of 32-QAM or 64- QAM.

On the other hand, the recognition of high packing factor modulations is more strongly influenced by the length of the signal, as the analysis shows that the 64-QAM modulation rate has doubled as the number of samples increased from the initial value of 5400 samples to a signal length of 80640 samples.

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