PARAMETER IDENTIFICATION IN RADIO FREQUENCY COMMUNICATIONS

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Abstract: *Modulation detection is an essential requirement for cognitive radio and in this paper is made a comparison between the time-frequency analysis and extraction of distinctive features of signals that allow identification of the type of modulation using the RPA. Using this method it was succesfully detected ASK, QAM and CPFSK modulations.*

Key words: *modulation, detection, RPA, ASK, CPFSK, QAM*

1. INTRODUCTION

The urgent need for resources led to over-exploitation of radio spectrum due to the exponential development of telecommunications technologies. It requires a multilateral approach to deal with optimization of spectrum resources in order to improve and exploit the full potential of the available radio.

This can be implemented both by reviewing current policies for managing radio spectrum and by distributing network intelligence computing through the use of advanced technologies and devices with increased processing power, which able to make decisions on different functional levels using , therefore, optimization algorithms and technologies for electromagnetic management resource allocation.

Intelligence in this context is synonymous with adaptability, or, in other words, changing the behavior of a network device under the action of external factors in the sense of performance optimizing.

A cognitive radio built on a software radio platform is a smart radio [4], context-aware which might be capable of autonomous reconfiguration by learning and adapting to the medium.

The main channel of perception in application is visualization of radio map constructed based on the measured spectral statistics parameters.

One of these parameters is the indicator RSSI (Received Signal Strength Indicator) [3] and as a supplement could be used the parameters obtained from RPA.

2. RECURRENCE PLOT ANALYSIS (RPA)

Recurrence method, RPA, is based on the representation of time series that characterize a process in m-dimensional space called phase space. Then this space is represented as a matrix that registers distance between points in phase space. If this distance is compared to a threshold, we will get the matrix recurrence. According to [1], the method can highlight different signal behaviors studied: steady, unsteady, cyclical fluctuations, etc. Trajectory in the phase space is performed by vectors that have samples as coordinates from time series studied:

$$\vec{v} = \sum_{k=1}^{m} x(i + (k-1) \cdot d) \cdot \vec{e}_k \qquad (1)$$

where $\vec{e}_k$ are unit vectors of state space axes, $x(\cdot)$ represent samples from time series studied, d is the time delay parameter and m is the size of phase space parameter.

These last two parameters are the most important parameters of the method.

After obtaining the phase space trajectory is obtained the distance recurrence matrix.

Its calculation (2) is based on determining the distance between points *i* and *j*, of the path.

Typically, this path is compared with a threshold (3):

$$D(\vec{v}_i, \vec{v}_j) = \|\vec{v}_i - \vec{v}_j\| \quad (2)$$

$$R(i, j) = \Theta(\varepsilon(i) - D(\vec{v}_i, \vec{v}_j)) \quad (3)$$

where $D(\vec{v}_i, \vec{v}_j)$ is the distance between *i* and *j*, Θ represents Heaviside unit step function and $\varepsilon(\cdot)$ is the selected threshold of recurrent matrix.

After the representation of distances on a colored scale, called distance matrix, if is applied the unit step function Heaviside having chosen a threshold, $\varepsilon(\cdot)$, will be obtained a recurrence representation that will highlight wheather the distance between *i* and *j* is less than $\varepsilon(\cdot)$ or is not.

This distance (below the $\varepsilon(\cdot)$ is shown by black dots placed in the matrix recurrence. In general ε is a constant and *D* is the Euclidean distance.

This distance can be calculated also using other metrics: maximum norm, the norm angular, etc. If the choice of the size of the encapsulation, *m*, it is too small, the trajectory in phase space is m-dimensional projection of the phase space trajectory real.

Thus, m-dimensional phase space trajectory contain adjacent points which in real space are not close.

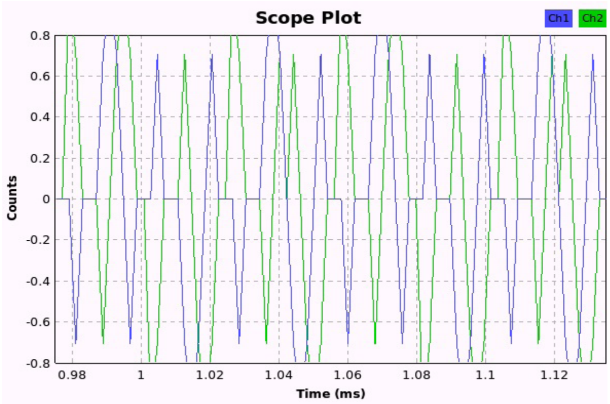
This space could lead to further conclusions that are not correct. However, if m is too great, the set of data comprising phase space and the number of calculations would increase excessively, and would result in a significant increase in computation time and resources used.

Therefore, the most used method for the choice of *m* is the method of false neighbors (FNN - False Nearest Neighbour) [2].

Encapsulation is the optimum size for the measure FNN is almost zero.

3.TIME-FREQUENCY DOMAIN ANALYSIS FOR DIGITAL MODULATION SIGNALS

In the case of the first simulated signal, an ASK modulated signal (2 bits/symbol, amplitude A=1, carrier frequency f_c=64khz), while time analysis seems to offer satisfactory solutions, since what matters is the instantaneous amplitude whitch can be easily detected in the time domain by applying a envelope detection.



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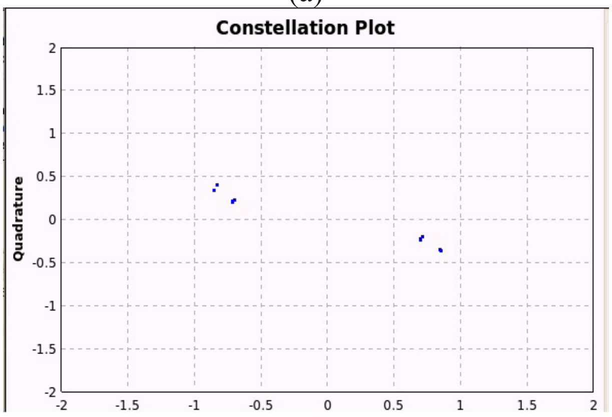

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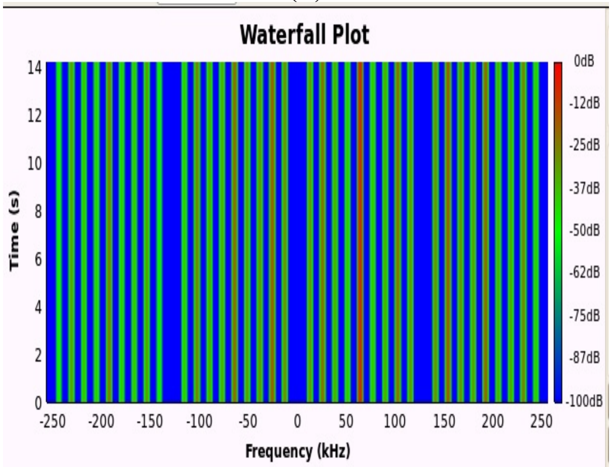

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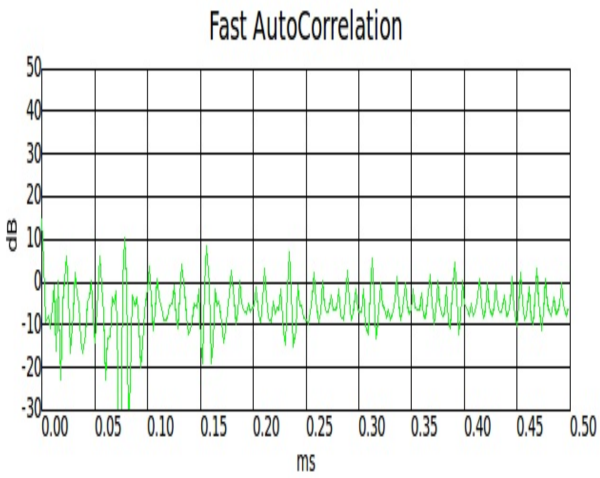

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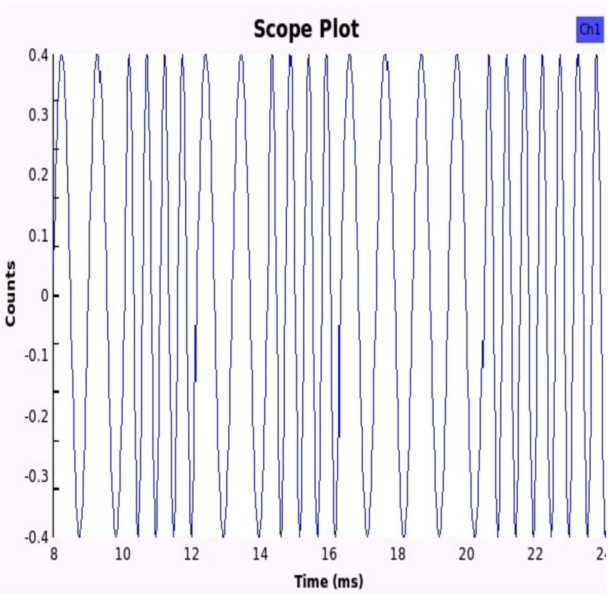
Fig. 1. (a): ASK signal; (b): ASK signal constelation; (c): ASK signal spectogram; (d): ASK signal autocorrelation

If signal is FSK modulated (the second simulated signal)(200 samples/symbol, 10 symbols, random signal source, 1000 samples) or PSK things are not the same, since the envelope is constant, what matters to these signals is frequency or instantaneous phase shifts and the characteristics can not be obtained directly by analyzing the field time (and even less in the presence of noise).



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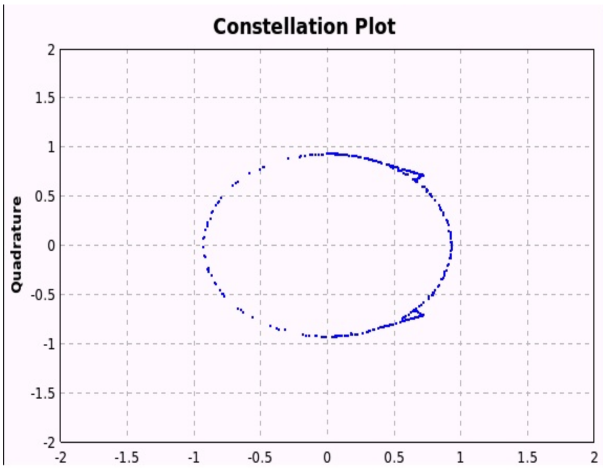

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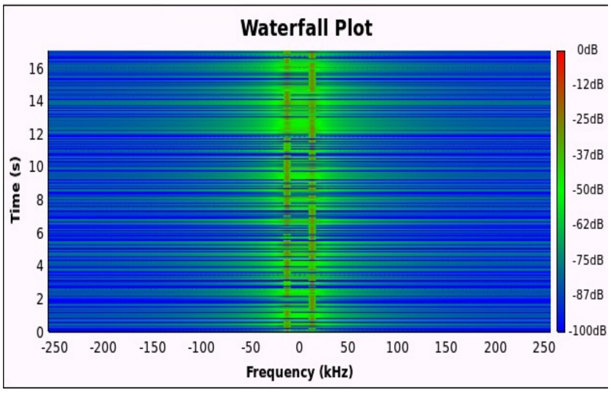

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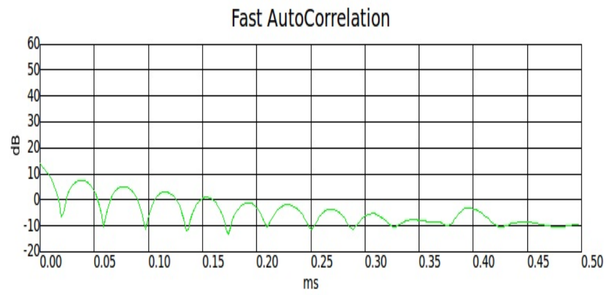

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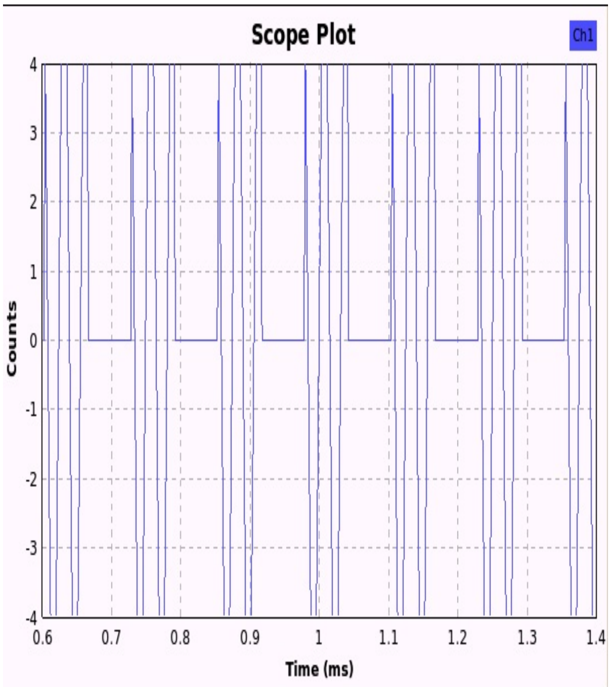
Fig. 2. (a): CPFSK signal; (b): CPFSK signal constelation; (c): CPFSK signal spectogram; (d): CPSFSK signal autocorrelation

What is specific to any type of digital modulation is that the modulated signal have stationary portions (minimum length equal to the duration of a symbol) and at the time of changing symbols sudden jumps occur in the signal structure.

This can be better seen in the time-frequency diagram and the recurrence of the signal.

An example is the third simulated signal, a QAM modulated signal(square wave signal source, f_i=5khz, amplitude A=1, carrier frequency f_c=20khz), that basically combines PSK with ASK modulation.



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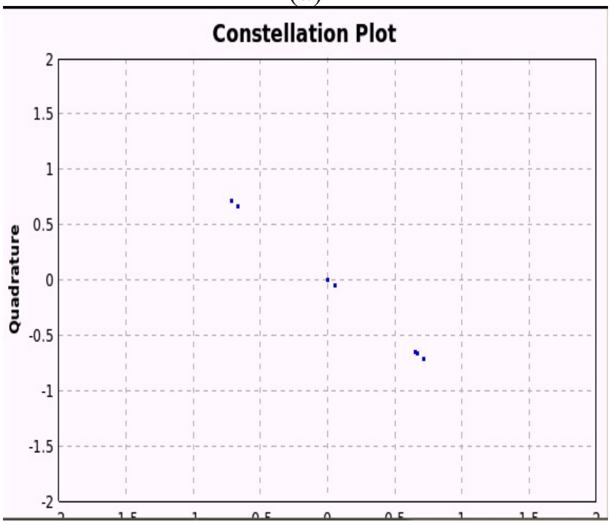

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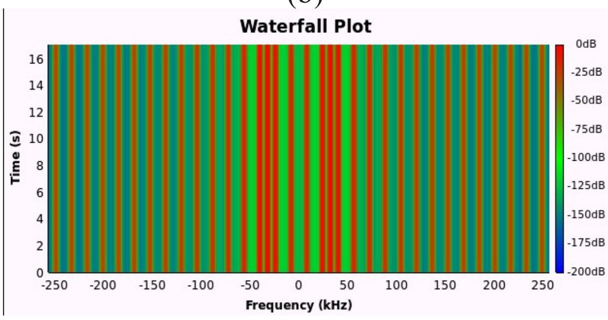

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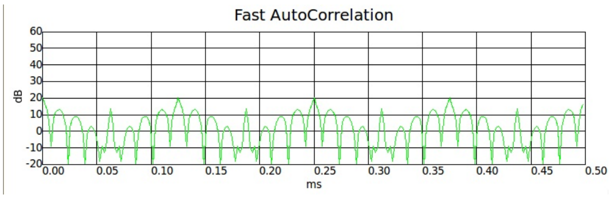

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Fig. 3. (a): QAM signal; (b): QAM signal constelation; (c): QAM signal spectogram; (d): QAM signal autocorrelation

For digitally modulated signals, the Fourier transform does not provide satisfactory solution since it only reveals the spectral content of the signal without giving information about the times at which something changes in the signal structure.

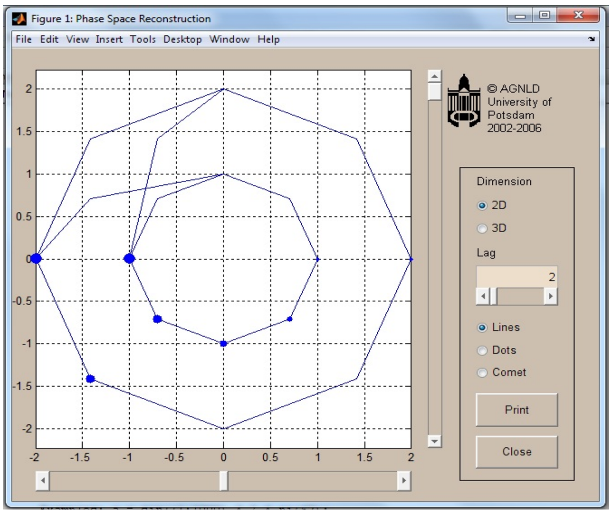
For example, the spectra of the two FSK modulated signals with different bit sequences will show nearly identical.

The spectrogram enables recognition (visually, at least) of ASK and FSK type of modulation.

4. RPA ANALISYS OF DIGITAL MODULATED SIGNALS

4.1 Recurrence diagram for ASK modulated signal (first simulated signal).

As the signal frequency remains constant, the graph is made up essentially of diagonal lines parallel to the main diagonal.



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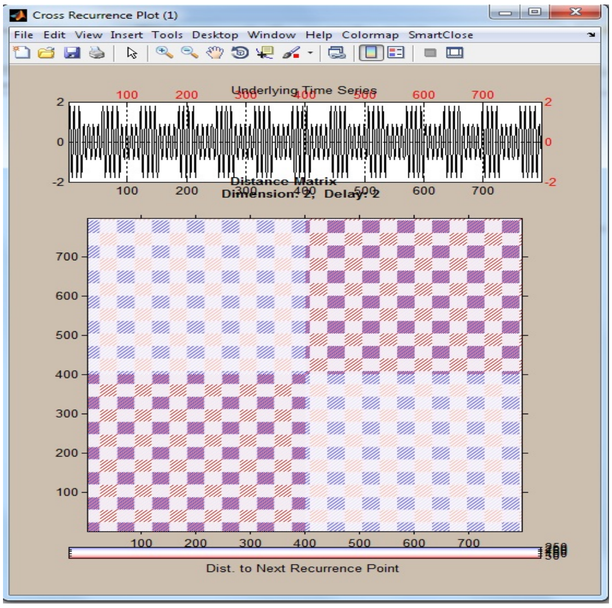

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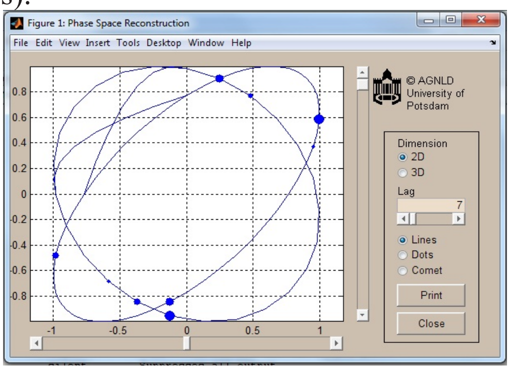
Fig. 4. (a): Phase space representation of ASK signal; (b): Recurrence matrix of ASK signal;

Information on the different signal amplitudes present were lost in the process of obtaining the matrix of recurrence (when the distance matrix binarization was done using it as a threshold parameter).

But transitions between areas with different signal amplitudes are visible in the diagram recurrence.

4.2 Recurrence diagram of CPFSK modulated signal (second simulated signal)

The moments of frequency hopping are visible on the recurrence diagram as areas of transition. Going on line identity it is observed when and how the signal frequency range (by observing the distance between the diagonal lines).



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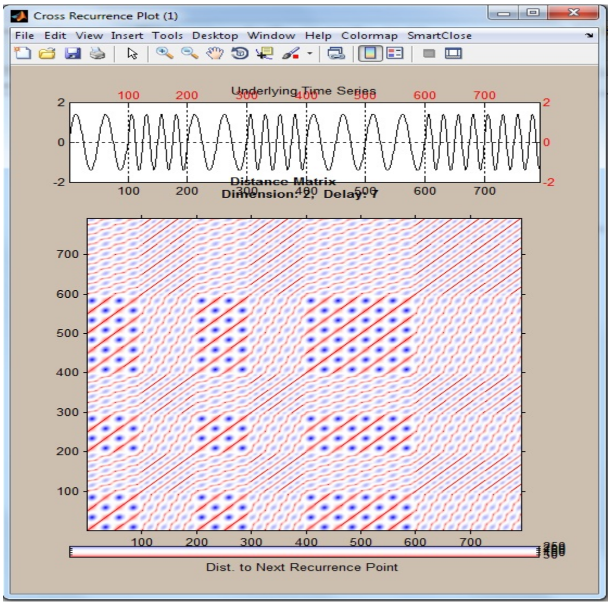

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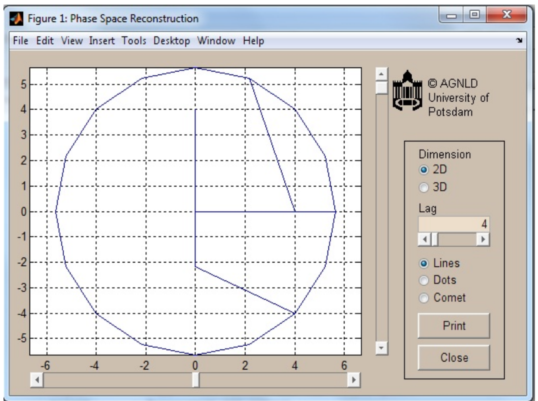
Fig. 5. (a): Phase space representation of CPFSK signal; (b): Recurrence matrix of CPFSK signal;

4.3 Recurrence diagram of QAM modulated signal

The moments of frequency hopping is visible on recurrence diagram as areas of transition. Going on line identity when and how to visually show the frequency and amplitude of the signal vary and the phase shift introduced by the discontinuities.



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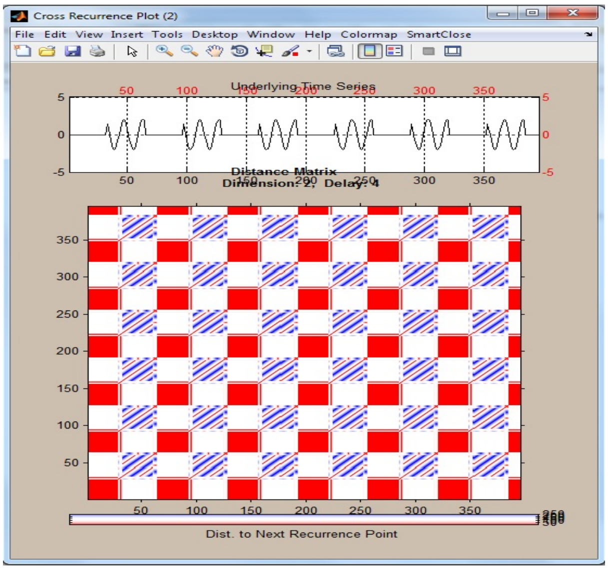

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Fig. 6. (a): Phase space representation of QAM signal; (b): Recurrence matrix of QAM signal;

5. IDENTIFYING THE TYPE OF MODULATION

ASK modulation type can be identified by inspecting the matrix of distances. If the maximum value of the blocks located on the main diagonal of the matrix of distances is approximately constant, then it is an ASK modulation type. FSK modulation type can be identified by inspecting the diagram recurrence. The diagram contains along the identity line blocks formed by diagonal lines (parallel to the identity line), spaced at a constant distance, the distance is approximately the same for all the blocks. In the corresponding recurrence diagram of an ASK signal continuity exists between the lines of all blocks and empty blocks can appear white (when comparing two segments of the signal amplitudes differ greatly).

Obtaining the period of the sine wave is done by summing the (normalized) on the diagonal of the matrix recurrence.

QAM modulations is visually identified using alternating signal areas containing the sine component represented by the lines thicker or thinner depending on the amplitude of the signal with areas where information is not transmitted.

CONCLUSIONS

In this paper it was studied the parameters of radio signals used in communications using two methods.

The first method aims at highlighting the parameters obtained by conventional measurements in the radio frequency signal level, bandwidth, the visual identification of the type of modulation, constellation of digital modulated signals and eye diagram.

The second method involves using signal recurrence for highlighting signal evolution in this way it can be characterized as a periodic or or irregularity , determining the fundamental frequency using recurrence histogram representation in phase space and visual identification of the type of modulation. Recording and processing of signals it was performed using a software radio implementation using GNU Radio.

This approach to the study of signal parameters using software radio can be useful for managing dynamically spectrum resource allocation based on the situation at the time. The great advantage of this method is the ability to adapt to different types of modulation. Its disadvantage is the high consumption of computing resources for the study of a consistent time series. In the detection of digital modulated signals, RPA can be used to provide a first indication of the type of modulation used.

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