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Recognition of Digitally Modulated Signal by ANN Algorithm

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ABSTRACT

According to the big usage of digitally modulated signal in military and civilian applications, and necessity of recognizing it, the importance comes from the above reasons in addition to how to get a method to classify a digitally modulated signal based on AI due to the high performance of classification and easy to use. The classification of received modulated signals is a mid-step between detection and demodulation of signal. Choosing the suitable parameters is for input modulated signal and with (ANN) assistant to recognize some of digital modulated signal such as (ASK,FSK,QPSK,BPSK, and QAM). Using computer simulation with Gaussian noise (0 dB to 10 dB) and ANN algorithm. The system of classification is consist from three parts are: 1- Pre-processing stage, 2- Network training stage, and 3- Network testing stage.

Key words: Classification, pattern recognition, ANN, parameters.

1. INTRODUCTION

Classification of Signal is very important part in military and civilian applications. Moreover, due to the usage of digital signals in modern technology like wireless telecommunications, whenever the most recent researches concentrated on identifying types of signals. AMR is a technique for classifying noisy and intercepted signals which has unknown modulation scheme. Techniques of AMR are Decision-theoretic, Statistical pattern recognition and Artificial Neural Networks (ANN).

AMR of digital signals is the biggest important process of signal problem in telecommunication fields. It is a middle level between signal interception with information recovery, which classify the type of modulation for the received signal automatically for additional process of demodulation and another tasks [1].The modulation scheme is the biggest important properties used in signal classification and monitoring. Modulation recognition systems (MRS) should be correctly classifying the incoming signal's modulation scheme in the presence of noise as shown in table (1) below:

Table 1: NN approach outperforms the decision tree in low SNR.

	20 dB	15 dB	10 dB	5 dB
ANN	100 %	100 %	100 %	100 %
DT	98.88 %	98.12 %	98.5 %	52.25 %

2. PROBLEM STATEMENT

There are many problems facing telecommunication engineers in their works, they want a suitable solution to get a reliable, and accurate results based on easy tools and techniques. The classification of modulated signal is one of these problems, and how to recognize the signal based on neural networks to use these signals in many applications in our life.

3. LITERATURE SURVEY

A- Ramakumar and Daryoush in 2001, presented the problem of classifying band-limited M-ary FSK signals, as this had proved difficult with the existing techniques. More specifically, they tried to develop and compare a decision tree and a neural network classifier for band limited FSK4 and FSK8 signal using zero-crossing techniques. For the neural networks, they tested a range of networks structures in a search for the smallest one. Based on the reasons below mentioned, the smallest is also the optimal structure [2].

- Smallest structure is the lease complexity and train fast which contain the lowest number of weights.

- Small structure minimizes the risk of suitable and losing of generalization ability.

- Larger network has low success ratio due to their pauper of generalization capability.

An optimal structure found to be hidden layer with two nodes using the tan-sigmoid structure. This network also trained using (LM) algorithm with a mix of samples with 20 and 10 dB SNR.

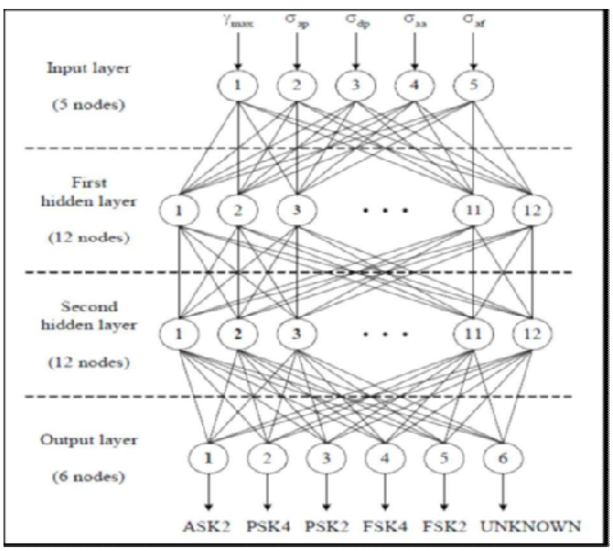
The result showed that the NN approach outperformed the decision tree, especially for low SNR table 1

In the suggested modulation classifiers, the key features used extracted from very three parameters of qualifying are: 1) phase, 2) frequency, and 3) amplitude.

The antenna arrays used to the capture of real signals. Generally, the antenna arrays applied for the planar, circular, or cylindrical. The real signal inputs into the systems of pre-processing. The real signals refined and segmented. Each segment has about 4096 samples. The actual signals segments are stored as a database [3].

Through MATLAB condition plan subsystem for removing key highlights. The base calculation for removing the key highlights of the real can exploit either the disconnected key highlights extraction or the on-line key highlights extraction. The calculation of the sections procedures of the genuine signs from the database.

Classifier of tweak set up on ANN fundamentally, this administration of framework for the programmed acknowledgment of simple and carefully adjusted sign. The classifier of tweak is comprise of an ANN dependent on back-proliferation. The ANN has 5 hubs in input layer, 12 hubs in first concealed layer, 12 hubs in second shrouded layer and number of the yield layer hubs rises to the quantity of carefully adjusted signs are (2ASK, 2PSK, 4PSK, 2FSK, and 4FSK) as shown in figure (1) below:



(MARIE RICHTEROVA, 2006)

Figure 1: Two hidden layers ANN architecture for digital modulation recognition

B-Ghani and Lamontagne in 1993, presented to use a (MLP) with back-propagation for AMR. They looked for a communication signals with 10 different modulations: AM, FM, ASK, QPSK, SSB-USB,SSB-LSB, NON-COHERENT FSK, CONTINUOUS-PHASE FSK, BPSK, and CW [10].

Where the signals simulated with SNR generated randomly between 5 and 25 dB, and only spectral features used as inputs features to estimate the spectral power density of the signal. They obtained the best results when they used the Welch Periodogram to produce an input vector of size 70. They found one hidden layer is enough to produce the best results as adding another hidden layer didn’t have any effect.

They addressed another problem was that no fixed rules exist on how to choose the size and topology for optimal performance of MLP. They use the pruning techniques called (OBD) technique, this technique trains a fully connected network and then deletes an essential number of weights without worsening and take a turn for the better the performance possibly. The result is shown by reducing the weight over a half using (OBD) technique and the performance was better than a fully connected network. Moreover, when compared the results from MLP approach with a classical statistical classifier called K-NN classifier, the MLP was longer to train and faster when running.

C- Aluisio, Lucas, and Luiz in SBrT 2012, presented a method to the automatic recognition via a measure of similarity that derived from Information Theoretic Learning (ITL), which called Correntropy coefficient [7].

Correntropy is a nonlinear similarity measured between two variables dislike many of unoriginal methods; the suggested way doesn’t required pre-processing of signal. In addition, the suggested AMR technique use an easy form of evaluating the correntropy coefficients, calculated over templates containing the common features of digitally modulated signals, in the classification task.

Numerical measures introduced demonstrate that the proposed AMR structure, in view of estimations of likeness by means of correntropy coefficient, it's so compelling in the assignment of order of double adjustments for simple and computerized signals influenced by AWGN commotion, that the utilization of an extra period of pre-handling for extricating highlight of the got signal isn't fundamental.

Researchers about on AMR can amass in couple strategies, either by insights from the receipt sign to characterize a (ML) work or by separating highlights of sign, concerning playing out the characterization utilizing diverse Pattern Recognition procedures.

The AMR process concerned two stages namely:

- Pre-processing level of signalto extracting feature.
- Suitable choice of the modulation form based on the selected signal features by the classifier system.

D- Ketterer, Jondral, and Costa proposed in 1999, a time-frequency approach, this scheme is a two-step process. First, autoregressive modeling used to estimate the carrier frequency. Next, the time-frequency information. It applied to estimate (phase ,frequency, and amplitude)shifts, allowing the separation of OOK, FSK2, PSK16, PSK2, PSK4, PSK8, FSK4, and QAM8 signals respectively. Simulations show modulation classification performance over 97% for SNR levels larger than 10 dB. Unfortunately, no simulations under real-world propagation channels made to further test the robustness of the method [8].

E- Polydoros, Long, and Chugg in 1996, present a maximum likelihood approach. Their method classifies OQPSK, BPSK, and QPSK modulation types contaminated with AWGN, using decision tree (DT) rules based on maximum likelihood criteria. Results show a 99% correct classification rate for SNR levels equal to 5dB or higher. However, their scheme requires some apriority signal information, like to the symbol rate and initial phase, making the whole process less practical [9].

4. SUBJECT OF WORK

The subject of research is trying to extract all the possible features such as concepts, variables such as amplitude, phase, frequency, symbol rate, SNR and all characteristics and parameters of the digital signal transmitted before it reaches the recipient end. And analyzed the values logically using Artificial Intelligence (AI) especially via ANN according to previous information and parameters values learned to the Neural Network (NN) then match the information and parameters values with previously learned features, compare the similarities and differences between it and study the current case to get a final decision of the transmitted wave and classifying it.

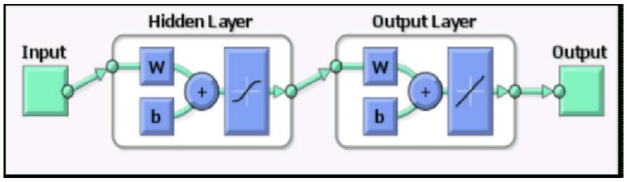
All of these processes carried out by using MATLAB programming software, including preparation, learning process, calculating values, an introduction of equations of each case to take the appropriate decision then classifying the transmitted wave to one of the modulated schemes. All that using the following two techniques and then choose which is better:

A) ANN by Scaled conjugate gradients (SCG) technique.
B) ANN by conjugate gradients (CONJGRAD) technique.

5. ANN CLASSIFIER FOR DIGITALLY MODULATED SIGNALS (MULTI-LAYER PERCEPTRON MLP)

The general function of ANN is to produce pattern of the output while given particular input pattern; the concepts taken from the brain's ability to recollect of the basis of certain input patterns, learning this mapping finish with similar method conceptually as the brain that is summing up from various models.

ANN is comprising of various straightforward computational gadgets that preferred the neurons in the human mind, connected with the weighted connection such as dendrites and axons, the most common types of ANN used in AMR is multi-layered Perceptron MLP or Auto-association Neural Network (AANN) [4] as shown in figure (2) below:



(Rada A.El-Khoribi, 2014)
Figure 2: The Structure of the Neural Network in ANN toolbox – MATLAB

Perceptron models a neuron by receiving weighted inputs and returning an all or nothing output depending on whether the weighted sum of inputs is less or larger than an adjustable threshold, Perceptron consist of the weights, the summation processor, and the adjusted threshold[5].

6. PATTERN CLASSIFICATION APPROACH

The computer that based on classification of patterns is important found with huge applications usage and areas like's medical applications, identificationbiometrically, techniques of classification of speech, fault detection, and optical character recognition, as I'll revolve around recognition of signal. Although that huge number of types of data such as there exists a generic pattern, classification approach, acoustic or radio signals, digital images, and sensor data, as shown in the figure 3. Its present first a little bit ofschemes of pre-processing performed. That may be operations of image or signal processing, such as filtering, segmentation, and transformation, to get a representation of uniform of the data as shown in figure (3) below:

After that, dimensionality-reducing process of the data by extracting as possible as smallest number of extracted features which emphasize an attributes of classes, and distinctions among classes. Then, the highlights fill in as contributions to the classifier, which execute the last distinguishing proof undertaking.

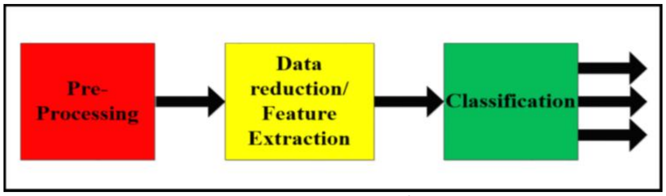


Figure 3: Generic Pattern Classification Approach

The classifier to execute the identification, it should get the information on what class represent by what data. Additionally figures out how to sum up, with the end goal that new and unclassified models arranged as needs be.

- Signal Pre-handling
- Feature Extraction

7. CLASSIFICATION METHODS

A classifier should use having got a feature vector to output a class label or, instead of that, a group of prospects or levels of confidence that sign to the results of prediction. The classification approaches of digitally modulated signals divided into two major groups [6]:

- Maximum Likelihood method.
- Pattern recognition method.

8. STRATEGY OF CLASSIFICATION

In this part of work, I'm going to create a neural network contain from some hidden layers to learn it with some parameters to extract suitable features helping me to classify our goal modulation signal.

To make that we need to identify and refer to the main strategies of signal modulation classification. As we referred to that previously, signal identification based on (ANN) common with three steps.

1- Features extraction of the modulated signal.
2- Learn the (NN) with the features extraction.
3- Testing the (NN) and getting results.

Thus, splitting the randomized data for data training, a validation data, and data testing which sets via 50%, 25%, and 25% respectively as shown in figure (4) below:

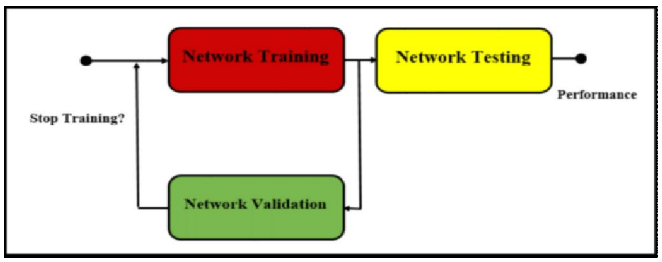


Figure 4: training, testing, and validation sequence

9. KEY FEATURES

The features extraction means to extract the values of parameters of the modulated signal in a specific time, so there are many useful parameters helping us to classify the group of modulated signals and recognize our goal scheme.

1- (BER) Bit error rate: is one of the most important parameters affected on the type of modulated signal identification, and mathematically explained as the following equation: BER= Number of bits / Number of errors.
2- (AWGN): Additive White Gaussian Noise: the most popular noise type found in telecommunication exactly in modulated signal and measured by dB.
3- (γmax): Maximum of spectral power density of the normalized-center instantaneous amplitude.
4- (σaa): Standard deviation of absolute value of normalized-center instantaneous amplitude.
5- (σa): Standard deviation of instantaneous amplitude in non-weak intervals of a signal segment.
6- (σaf): Standard deviation of absolute value of normalized-center instantaneous frequency.
7- (P): Spectrum symmetry value.
8- (σap): Standard deviation of absolute value of non-linear component of instantaneous phase.
9- (σdp): Standard deviation of direct value of center non-linear component of instantaneous phase.
10- (v20): Combined order moments, based on the Joint Power Estimation and Modulation classification algorithm.
11- (X): Mean of amplitude.
12- (β): Power of signal
13- (Sxx): Power spectral density.
14- (φ(t)): Phase offset.
15- (f(t)): Frequency Offset.
16- (Ns): Number of samples per segment.
17- (S): Hidden layer nodes.
18- (Eb/No): Ratio of power of bit to the power of noise.

10. DIGITAL CLASSIFICATION

Digital automatic modulation recognition (DAMR). Using MATLAB code, the message at first modulated on the baseband. The five modulated schemes used are (ASK , FSK , QPSK , BPSK , and QAM) and the three stages involve in developing the DAMR discussed in the following:

10.1 Pre-processing stage

At this stage, Feature keys extraction carried ou. The feature keys extraction carried out in order to get input feature keys for the DAMR classifier. Feature keys compute the smallest number of features from the raw modulated signals extracted.

The keys of feature choosing is a trade-off among reducing the number of features to minimize the ANN input size, as long as the complexity of computational and containing all the necessary features for the reliable recognition for the digital signal modulation schemes. As for the analog classifier, a set of feature keys that are used in developing the digital classifier for this research. The seven feature keys are extracted from a(t), and φ(t) of the simulated signal as shown in figures (5, 6, 7, 8, 9, 10, 11, and 12) below:

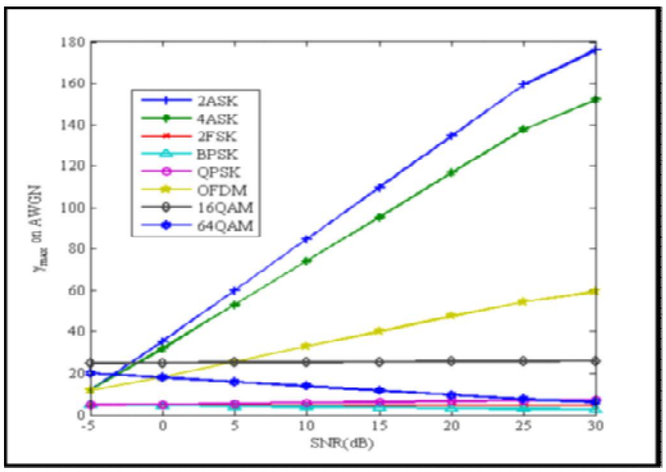


Figure 5: Variation of γmax with SNR for digital signal

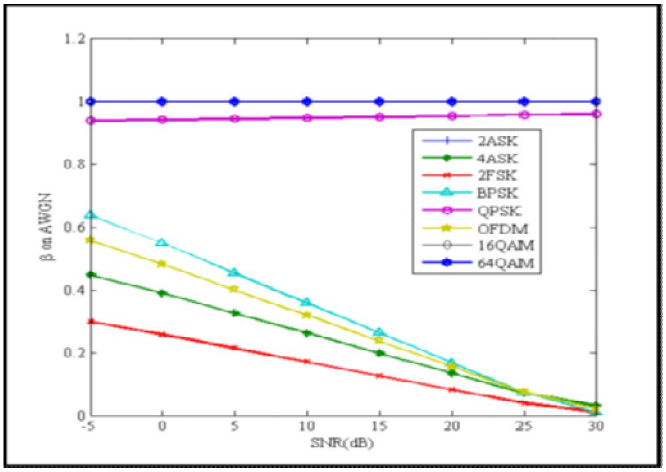


Figure 6: Variation of β with SNR for digital signal.

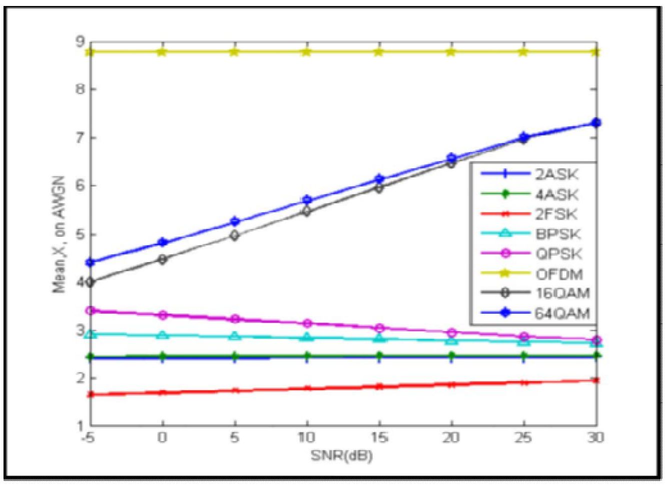


Figure 7: Variation of X with SNR for digital signal

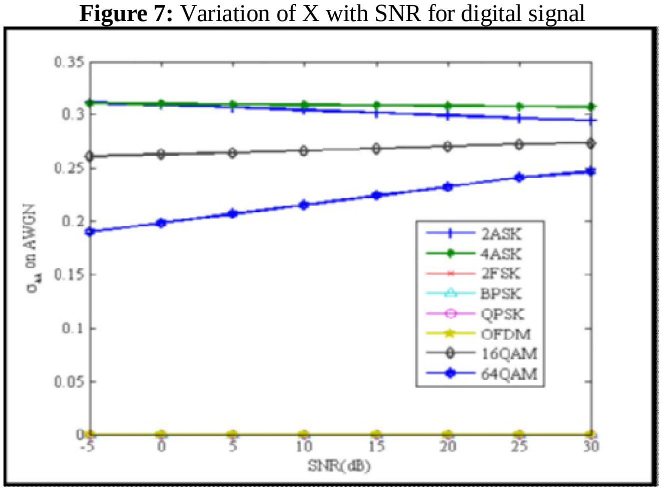


Figure 8: Variation of σaa with SNR for digital signal

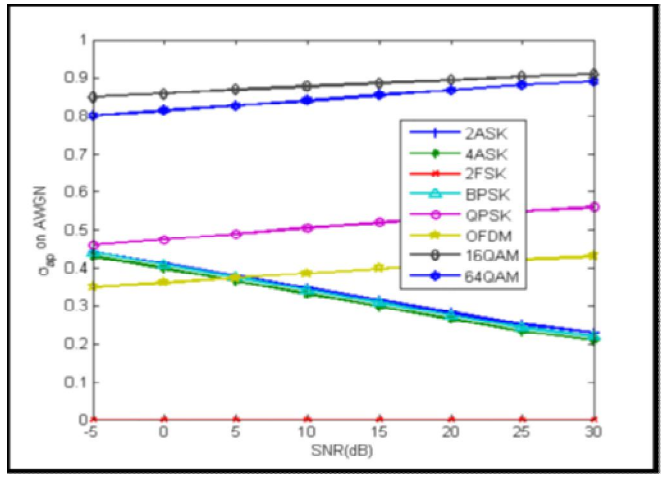


Figure 9: Variation of σap with SNR for digital signal

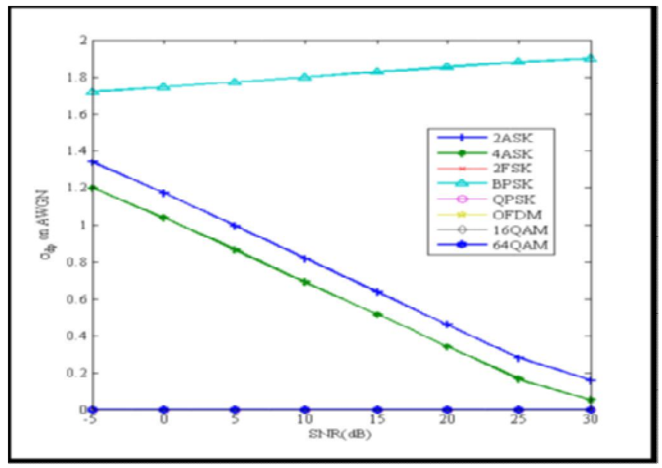


Figure 10: Variation of σdp with SNR for digital signal

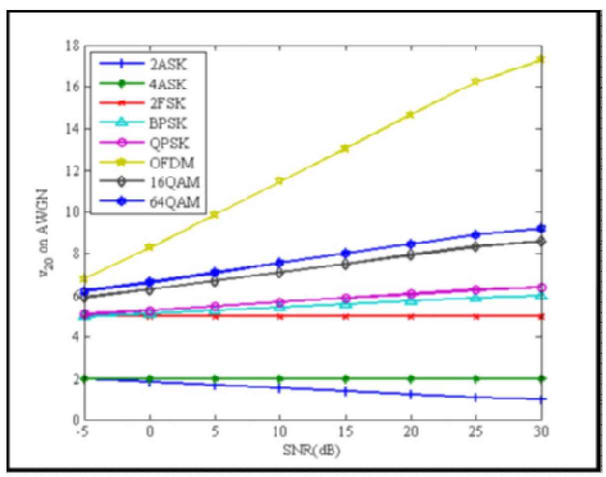


Figure 11: Variation of ν20 with SNR for digital signal

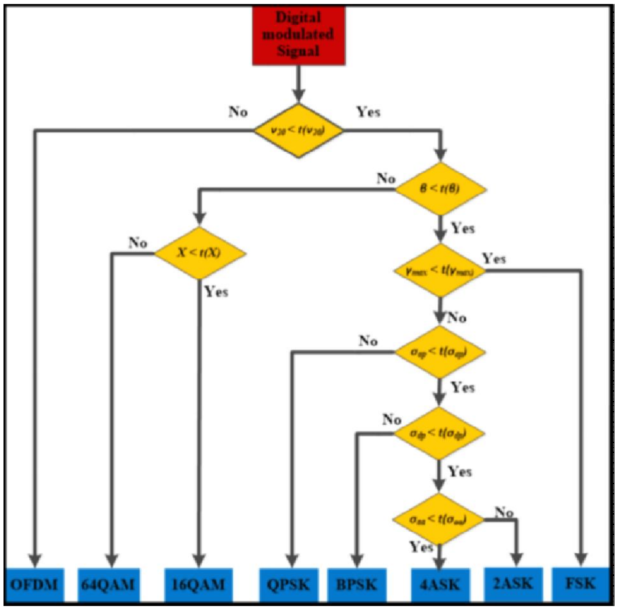


Figure 12: Flowchart for the Developed DAMR of digital signal

10.2 Network Training stage

It is the second stage of AMR development that discussed the digital automatic modulation recognition (DAMR) classifier, training and development of. The architecture of the developed DAMR having the statistical keys for extract features using the MLP network and compare as the input data sets. The MLP composed of just one input layer, fifteen hidden layers and also just one output layer of computational nodes. Seven nodes completely connected correspondingly to the number of input features, also seven nodes in hidden layer and eight nodes in output layer corresponding to the number of goals as shown in figures(13, 14, and 15) below:

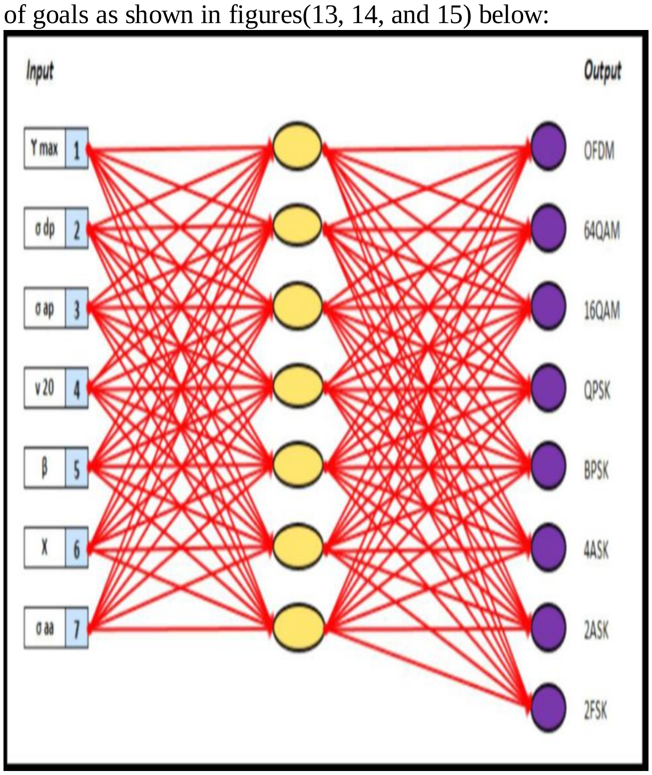


Figure 13: DAMR architecture of analog signal

10.3 Network Testing stage

After development and training stages of classifier or network, the classifier performance evaluated by use 25% of all generated data as a test data. It carried out of different SNR values (0, 5, and 10) dB as shown in tables (2, 3, 4, and 5) below:

Table 2: Specifications for the Developed DAMR

Item	Parameters	Value
1-	Type of NN architecture	Feed-forward
2-	Number of neuron in input layer	7
3-	Number of neuron in hidden layer	7
4-	Number of neuron in output layer	8
5-	Coefficient of weight-decay	0.01
6-	Activation function in hidden layer	tanh
7-	Activation function in output layer	Logistic
8-	Maximum number of epochs	150
9-	Learning algorithm	**SCG**

Table 3: Developed DAMR Success Recognition Rate

Modulation scheme	Percentage of success recognition rate at different SNR		
	0 dB	5 dB	10 dB
2ASK	99.32	99.60	99.94
4ASK	99.58	99.79	99.92
2FSK	99.90	99.93	99.98
BPSK	99.97	99.98	100
QPSK	99.92	99.95	99.98
OFDM	99.85	99.90	99.97
16QAM	99.67	99.82	99.86
64QAM	99.32	99.60	99.65
Overall success rate (%)	99.70	99.82	99.91
Operational time was taken (millisecond)	0.48	0.49	0.50
Average operational time = 0.49 millisecond			

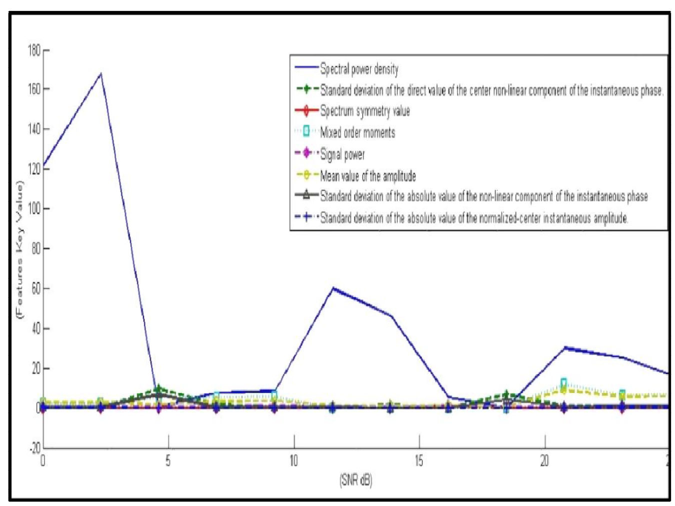


Figure 14: Features key vs. different SNR

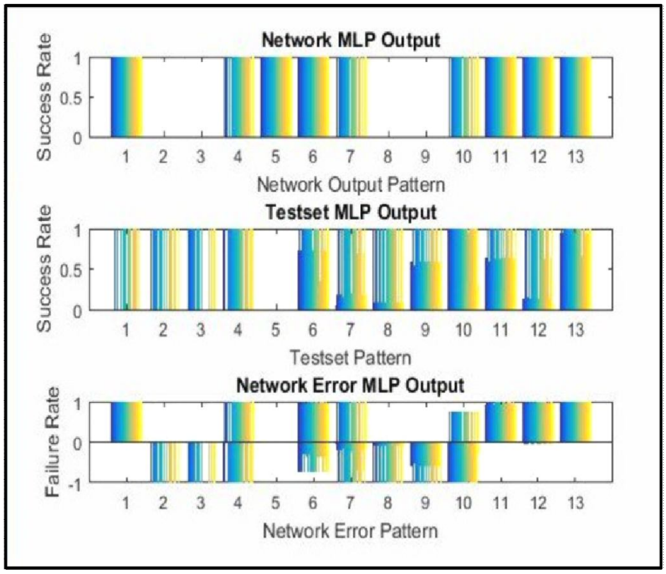


Figure 15: Typical Network Output Result of the Developed DAMR Classifier

Table 4: Input data value for DAMR

	2ASK	4ASK	2FSK	BPSK	QPSK	OFDM	16QAM	64QAM	NONE	γ_{max}	σ_{dp}	ν_{20}	β	X	σ_{ap}	σ_{aa}
2ASK	99.97	0.00	0.00	0.00	0.00	0.00	0.00	0.00		121.35	0.03	1.80	0.35	2.55	0.30	0.30
4ASK	0.00	99.96	0.00	0.00	0.00	0.00	0.00	0.00		168.00	0.03	2.00	0.37	2.60	0.31	0.32
2FSK	0.00	0.00	99.95	0.00	0.00	0.00	0.00	0.00		0.15	9.47	5.00	0.25	1.70	6.39	0.00
BPSK	0.00	0.00	0.00	99.97	0.00	0.00	0.00	0.00		7.40	1.77	5.20	0.40	2.95	0.28	0.00
QPSK	0.00	0.00	0.00	0.00	99.96	0.00	0.00	0.00		8.10	0.49	5.50	0.95	3.40	0.50	0.00
OFDM	0.00	0.00	0.00	0.00	0.00	99.96	0.00	0.00		30.00	0.75	11.70	0.40	8.90	0.39	0.00
16QAM	0.00	0.00	0.00	0.00	0.00	0.00	99.92	0.00		25.00	0.20	6.30	1.00	5.50	0.87	0.26
64QAM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	99.87		15.00	0.01	6.80	1.00	5.80	0.82	0.21

Table 5: Confusion matrix of results

	2ASK	4ASK	2FSK	BPSK	QPSK	OFDM	16QAM	64QAM
2ASK	99.97	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4ASK	0.00	99.96	0.00	0.00	0.00	0.00	0.00	0.00
2FSK	0.00	0.00	99.95	0.00	0.00	0.00	0.00	0.00
BPSK	0.00	0.00	0.00	99.97	0.00	0.00	0.00	0.00
QPSK	0.00	0.00	0.00	0.00	99.96	0.00	0.00	0.00
OFDM	0.00	0.00	0.00	0.00	0.00	99.96	0.00	0.00
16QAM	0.00	0.00	0.00	0.00	0.00	0.00	99.92	0.00
64QAM	0.00	0.00	0.00	0.00	0.00	0.00	0.00	99.87
NONE								

11. SUMMARY

The importance of this work is focusing on AMR for digital modulation schemes by DAMR. This classifier are capable to classify any modulated scheme without pre-knowledge about the modulated schemes.

The results obtained using training algorithms SCG and CONJGRAD display SCG s quicker than CONJGRAD training algorithms.

12. CONCLUSION

Our contribution of this work is on the development of DAMR based on ANNs, which can automatically recognize all forms of modulation schemes. The paper is primarily focus in meeting one of the objectives of this research work.

Algorithm of classification is an important part for modulation recognition system. There are two methods grow for the classification based on ANNs: the first one based on SCG and the second based on the CONJGRAD training algorithms.

In the SCG, the possibility of each single key feature for each single modulation scheme with variance SNR results got. Acouple of methods compared and the results show that the performance of the ANNs based recognition system is superior to the decision classifiers based on way with less SNR values. Both of the suggestedidentification systems are capable to discriminate ASK2, ASK4, 2FSK, BPSK, QPSK, OFDM, 16QAM, 64QAM, and NOISE at SNR>5 dB with a success rate 100%.

Also, we have also compared the performance of this algorithm with a number of classifiers in the literature as shown in table (6) below:

Table 6: Results among different classification approaches with ANN

Classification Approach	15 dB	10 dB	5 dB
DT	98.12 %	98.5 %	52.25 %
Fully connected	78%	70%	63%
Hierarchical	90%	78%	63%
Maximum likelihood	99%	97%	96%
Time frequency	97%	90%	87%
ANN	100 %	100 %	100 %

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