

# Automatic Modulation Recognition for Digital Communication Signals

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*Abstract- Different modulation techniques are used for different signal transmission. These techniques give versatility to the transmission medium as well as make user easy to work in such computational field. With prior no knowledge of data transmitted and various unspecified parameters at receiver side like the carrier frequency, phase offsets and signal power etc., blind detection of the modulation is challenging. This becomes more difficult at the time of fading. That's why recognizing these modulation schemes is useful for various technical purposes and especially quite significant for the military, wireless and COMINT applications. Digital modulation recognition is based on some parameters especially statistical parameters. Till now various recognition algorithms have been developed and still developing. The recognition algorithms can be divided into two major groups 'maximum likelihood approach (MLA) and pattern recognition approach (PRA). In this paper we are emphasizing on the theoretical information of these techniques of modulation recognition along with ANN modulation recognizer for m-ary modulation techniques. A general application of modulation recognition in field of SDR is also proposed.*

**KEYWORDS-** Maximum likelihood, Pattern Recognition, Modulation Detection Scheme, Software Defined Radio, Artificial neural network

## I. INTRODUCTION

There are so many communication signals all available with different types of modulation and different frequencies. It is necessary to identify and closely monitor these signals for few applications. Few of the applications find place for example signal confirmation and spectrum management, few other applications are also meant for military purposes for example electronic warfare and threat analysis. For electronic warfare techniques electronic support measures [1] [2]. system play a crucial role as a means of information which is needed to conduct electronic counter measures (ECM), threat detection, Warning and target acquisition and homing. Under wireless communication due to the expanding of the Demands particularly in the consumer electronics applications,

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It has resulted in comprehensively building the reliability and also the quality of service. This scenario has created a need to present intelligent add-ons the incoming signal. Modulation types are supposed to be the signal signature in for communication Intelligence (COMINT) [3]

First of all; if we apply the signal to an improper demodulator it might partially or totally damage the signal information data content. Second of all when we have identified the modulation type, proper demodulator can demodulate the signal to get back the information. Hence, modulation recognition is an important and crucial and functionalities in the wireless devices, which has led to the future technology of Cognitive Radio (CR) one of the most crucial tasks of a CR (Cognitive radio) Receiver is the total automatic recognition for the modulator step to recover the signal that is exactly transmitted.

The communication signals that are intercepted they have a great probability of uncertainty because of the inability to unidentified types of modulation as well as noise. Hence, a lot of modulation classification algorithms have been generated and implemented. Feature extraction along with classification algorithm stages form important stage of a modulation recognition system. [1] Efficiency and effectiveness of the modulation recognition system almost entirely depends on the initial knowledge of few of the signal parameters and on the selection of the important features and classification algorithm. During the course of this paper, we have provided a theoretical overview of modulation Recognition approaches [8] Which are based on statistical properties for some digital modulations including ASK2 (Amplitude Shift Keying2), ASK4, PSK2 (Phase Shift Keying 2), PSK4, FSK2 (Frequency Shift Keying 2), FSK4, QAM etc .Further its application in field of SDR, COMINT is discussed in last section of the paper.

## II. WHY WE REQUIRE MODULATION RECOGNIZERS?

Many veiled and manifest operations require classification of modulation whether analog or digital modulation technique because it is necessary to know the type of incoming signal. How to observe and identify modulated signals is necessary to know about valuable information [12] [13] [14]. The recognizers help to distinguish the signal in presence of (AWGN) along with presence of other signals the process of recognition is a most important intermediate step between the detecting and demodulating process.

## III. KEY FEATURES FOR EXTRACTION

The basic features and characteristics which are used in case of classification are instantaneous amplitude, frequency, and phase and power spectral density of signal. [10]

The signal squared and the signal quadrupled is used to come out with the following key features of the intercepted signal:

- 1) Mean of the envelope
- 2) Variance of the envelope
- 3) Magnitude and location of the two largest peaks in the signal spectrum
- 4) The magnitude of spectral component being twice carrier frequency of squared signal
- 5) The magnitude of spectral component being four times of carrier frequency of Quadrupled signal. The various other statistical characteristics have been developed from the signal's power spectral density, instantaneous amplitude, frequency and phase. Normally the classification of ASK2 and PSK2 is impossible because in almost all the cases their constellations act as an important parameter. Various statistical parameters based on the mean, variance, and histograms have been used with AMC [6] [11]. All the statistical parameters are calculated using the basic key features. But, most of the features need some of the signal parameters for example carrier frequency, pulse shape, time of arrival, initial phase, symbol rate, signal to Noise ratio, to be known or to be extracted.

## IV. MODULATION RECOGNITION APPROACHES

Over the course of last 20 years a lot of modulation recognition techniques have been developed. Azzouz and

Nandi made use of two vastly different Approaches [8] [11] [9] in order to classify modulated signals almost all the approaches can be divided into two major groups:

- 1) Maximum likelihood approaches
- 2) Pattern recognition approaches

These approaches are further explained in brief in the next section of the paper.

### 1.1 Maximum likelihood approach

Under maximum likelihood technique, the test statistics needs advance knowledge about the signal, although the decision rules are pretty simple. The maximum likelihood approaches are able to provide optimal solution by minimizing the possibility of false classification if all other possibilities are met. Within the maximum likelihood approach, AMC (Automatic modulation classification) is built considering it as a multiple composite hypothesis-Testing problem, and also the histogram is applied to AMC. Hypothesis is solved with the help of different maximum likelihood techniques.

Different implementations of maximum AMC approaches have already been proposed for ML-AMC

which is based on various possibilities regarding the unknown signal. In the maximum likelihood approach as shown in fig.1, the classification is interpreted considering [10] it as a multiple hypothesis testing problem, where a hypothesis  $H$  is arbitrarily allotted to the  $X_i$  modulation type of  $m$  different types.

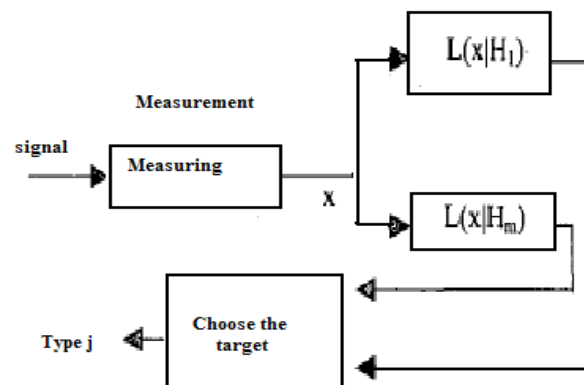


Fig.1 General Maximum likelihood classifier

The ML classifier is based on the conditional probability density function. Different tests under different scenarios have been brought forward for AMR based on different possibilities and conditions.

If the probability density functions of the above mentioned features are already known, [10] an average likelihood ratio test can be used to make available a perfect solution under modulation estimation.

Under average likelihood ratio test, the unknown parameters, for example a noisy signal symbol are considered as a random variable with  $M$  number of hypothetical probability density functions and also the logarithmic likelihood function for the  $i(t)$  hypothesis is calculated.

If the true probability density functions meet with the hypothetical ones, the results are supposedly maximized. [12] In other words, the average likelihood ratio test will give improvised solutions which will be based on the distributions of errors instead of the instantaneous errors. However, the average likelihood ratio test modulation classifier is not only computationally intensive but it also needs accurate time, frequency, and phase estimations in order to convert the IF data to near the baseband.

When probability functions of the various features are not available, the generalized likelihood ratio test (GLRT) might be used which considers all the available candidates as not known deterministic values. The generalized likelihood ratio test [8] is not an optimal estimator which is not the case in average likelihood ratio test but it has simple implementation.

Generalized average ratio test might also be seen as a variance test with is having time-varying mean values. [12] Variance test is generally used modulation estimation in order to measure the feature fluctuations but it is pretty sensitive to the additive noise and channel fading.

The histogram test is also used for the linear Modulation classification [7] [8] this test makes use

Of very less power for processing purpose. Variant features like phase, phase differences frequencies, distributions of amplitudes are plotted like histograms. Modulation scheme is finally recognized by statistically comparing the matching templates and histograms.

### V. PATTERN RECONITION APPROACH

In case of statistical pattern recognition approaches, complicated decision rules are involved. General pattern recognition system consists of three parts: sensing, feature extraction and decision procedures.

The pattern vector presents features of a pattern or object. [15] The pattern vector might have useless information.

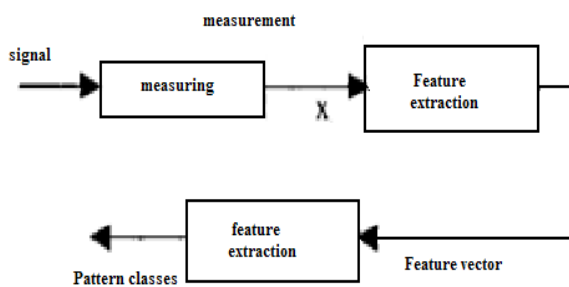


Fig.2 General Pattern recognition system

Dimensionality of the pattern space should be decreased in order to simplify the design of the computational effort. In it decision procedure might contain decision functions, distance functions, or neural networks. These approaches provide good results for different values of SNR (Signal to noise ratio).The decision part requires artificial neural networks.

### VI. ARTIFICIAL NEURAL NETWORK

ANN is a well known mathematical model based on Biological neural network. ANN is good in finding the desired pattern of the data. IT also establishes the relationship between the input and output. They have been in use for many years for the purpose of modulation recognition [18] and even in present times also they are used with different genetic algorithms. The best quality of ANN is they can easily work in complex environment where other computations get fail. ANN is good in non linear mapping of the signal, as well as self adaptability. Thus ANN is employed for recognizing different M-ary modulations.

### VII. ANN MODULATION RECOGNIZER FOR M-ARY MODULATION TECHNIQUES

The modulation recognizer which is based on the ANN approach is shown in fig.3. This recognizer is considered

to differentiates between m-ary ask and fsk and it consists of the three main blocks

- 1) The preprocessing block wherein the key input characteristics are extracted from each and every part of the signal frame.
- 2) The training and learning blocking order to make way for classifier structure
- 3) The test block in order to make a decision about the modulation type of a signal.

The very first is used to differentiate in between the given Modulation types apart from the decisions related to the estimation of the number of levels in the M- ary amplitude shift-keying (MASK) and the (MFSK) frequency shift-keying.

The differentiation between ASK2 and ASK4 is done through the use of another different network known as the second network, and also the differentiation between FSK2 and FSK4 is done through the use of a third network.[18]

From the first network, only two of the output decisions- namely MASKS decision and MFSK decision -need the additional two networks to complete the differentiation. The second and third networks calculate the number of levels of the above mentioned two signals.



Fig.3 Functional blocks of ANN

In case of the first network, it came to notice that the best ANN consists of three neuron layers. First hidden layer makes use of the log-sigmoid as the activation function; [1] [6] linear function is used as the activation function in case of the second hidden layer and the third layer makes use of the log-sigmoid function as the activation function.

In the case of second and third networks, only one activation function (log-sigmoid) is used making it very simple. But in case of excess of unnecessary information their performance gets poor in terms of Convergence so other algorithms or genetic algorithms are used along with this that increases the speed and recognizing ability.

### VIII. APPLICATIONS FOR COMINT

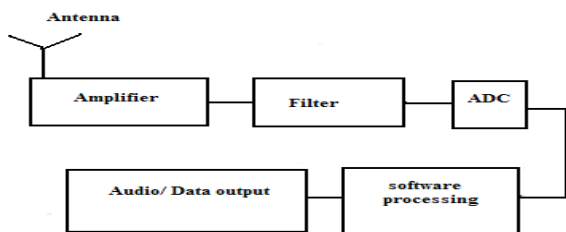
Historically, COMINT (Communication Intelligence) systems have dependent on the manual modulation recognition of measured parameters in order to provide classification of different emitters. But, recently automatic modulation recognition systems have come into picture. [12]

One of the historic models of modulation recognizers makes use of a bank of demodulators; each one of them is designed for only one type of modulation.

By listening to the demodulator outputs we can decide the modulation type of the received signal. [13] [16] this requires highly skilled operators as well as long signal durations. The Automation of this kind of recognizer is performed by applying a set of intelligent decision algorithms at the demodulator outputs. But, the implementation in this scenario is complex and needs excessive computer storage. The number demodulators used limit the modulation types that can be recognized. Automatic modulation recognition seems to be more effective than manual modulation recognition because it can integrate the automatic modulation recognizer with an electronic support measurement [22] [25] receiver which would allow an operator to enhance his efficiency and his ability to analyze the various activities in the frequency band of interest. Hence, in advanced ESM systems, sophisticated electronic machines are used instead of an operator. The main Purpose of any surveillance system is supposed to be threat recognition by comparing the features of the intercepted emitters with a catalogue of reference characteristics.

### IX. APPLICATIONS FOR SDR

SDR signify the new generation of the radio communication which is quite important for the rise of 4G as these systems are quite flexible offering interoperability as well as even reduce the operation cost. These systems convert hardware functions to the software realization. SDR receiver shown in fig.4 do not require any permissible change in the Integrated circuit for different digitally modulated signals. A RF front end is basically employed in a particular SDR system.



**Fig.4 Block diagram of SDR receiver**

Antenna signal is filtered, amplified according to the need and finally converted from analog to digital signal. For digital signal processing proper software is employed performing different functions like of converting pass band to the baseband and demodulating the signal. DSP or general purpose processor is taken in use for processing the software. Less bit rate requirement of the 4G systems is fulfilled by maximizing the channel capacity with the use of dynamic channel assignment scheme and of Adaptive modulation scheme. SDR receiver used is capable of identifying the appropriate demodulation scheme for signal having unidentified modulation type.

### X. CONCLUSION

The basic aim of the paper is to explain about the different automatic modulations recognition algorithms along with a number of key features of extraction proposed for these recognizers. It has been found that when using maximum likelihood approach, it depends on mean, variance and used signal parameter pulse shape, time of arrival initial phase and requires more signal parameters knowledge as compare to pattern recognition approach. While pattern recognition, it provides an optimal solution for different SNR values using artificial neural network. Application of recognition approach in the field of COMINT as well as SDR is also discussed in brief.

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