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Introduction

1.1 MOTIVATION

Blind signal modulation recognition aims to identify the type of modulation scheme in the received RF signal distorted in the channel. It is an intermediate step between signal detection and demodulation and has significant roles in many military and security applications, spectrum management, and intelligent modems. Automatic modulation classification (AMC) is currently an important in the design of Cognitive Radio (CR), where it is used at the front end to detect the modulation scheme. Modulation identification carries paramount importance in universal modems and is a precursor to forward error correction (FEC) decoding. Therefore robust blind modulation identification acts as a foundation of any Communications Intelligence (COMINT) system. AMC is currently an important research area in intelligent radio systems, including CR and software defined radio (SDR).

In military and security applications, friendly signals must be transmitted securely and should be received properly, whereas unfriendly signals must be recognized and jammed. To prepare the jamming signal, one should have information on the transmitting signal's frequency band and modulation type. A signal detector detects the signal in the particular frequency band. The modulation classifier estimates the modulation type in the unknown detected signal. A high-energy signal with matching modulation in the same frequency band is prepared to change the property of the transmitted signal generated through the adversary unit to halt the communication.

Another application of AMC includes spectrum monitoring and its proper usage. Every operator is provided with the specific band within which it has to communicate. International telecommunications union (ITU), an agency of the UN, which coordinates the use of the radio spectrum globally, provides spectrum licenses to different regions of the world where they use it for communication with the set standards. AMC systems can identify the unlicensed transmitters or the transmitters which are not working with the approved standards. Monitoring the spectrum occupancy also serves the purpose of future allocation of spectrum and interference-free communication. Due to the continuous increase in the demand for wireless connectivity, the licensed spectrum has become overcrowded. Further, the allocated spectrum remains idle most of the time which leads to underutilization of the spectrum. AMC systems can serve the purpose of finding the licensed spectrum available to be used. If the primary user is not using the channel, a secondary user can be allowed for communication.

AMC is also used in link adaptation and coding, where the modulation type used at transmitter adapts according to channel condition to increase transmission reliability. Transmitter chooses the modulation type from the pre-defined set of modulations called the modulation pool to complete the process of modulation. When the channel is noisy, to maintain high link reliability, the transmitter chooses the lower order modulations like Binary Phase Shift Keying (BPSK), or Quadrature Phase Shift Keying (QPSK) for a low probability of bit error. For the conditions when a channel is clear, higher-order modulations like 16-QAM (16-Quadrature Amplitude Modulation) and 64-QAM (64-Quadrature Amplitude Modulation) are chosen for high throughput. If the AMC system is deployed at the receiver, it can significantly increase the data throughput by saving bits

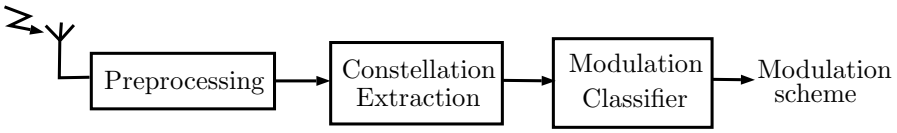


Figure 1.1 : Basic block diagram for modulation classification

in each frame containing information of transmitted modulation type.

1.2 PROBLEM FORMULATION

Let the transmitter, equipped with adaptive modulation and coder, transmits the RF signal modulated with one of the modulation schemes from the modulation pool. This modulation pool has a finite set of modulation schemes. The aim of the receiver, deployed with the AMC system, is to estimate what modulation scheme has been used at the transmitter. The basic block diagram of an AMC system used in the thesis is shown in Figure 1.1. AMC system consists of two parts: Preprocessing and Modulation classifier. At the receiver, the signal's carrier frequency is first estimated in the frequency band for which the AMC system is designed and the signal is downconverted to zero center and sampled at a high rate satisfying the Nyquist criterion. Downconverted and sampled signal $y[n]$ can be expressed as

$$y[n] = \alpha x[n] + w[n] \tag{1.1}$$

α comprises of different channel effects, and $w[n]$ is additive white Gaussian noise (AWGN). $x[n]$ is transmitted baseband signal. Signal properties and channel effects like symbol rate (SR), symbol timing offset, carrier frequency offset (CFO), and phase offset are estimated and corrected. All these estimations and corrections form the first part, i.e., the preprocessing part. $x[n]$ is formed from the fixed set of symbols associated with a modulation scheme from the modulation pool. The modulation classifier aims to estimate the modulation scheme from this pool used by the transmitter by observing the extracted symbols. The performance of the classifier is based on different criteria. Some classifiers achieve higher accuracy of classification, which means in a noisy environment, they estimate the modulation scheme used by the transmitter correctly. However, this accuracy comes with the high computational complexity. Some fields require real-time classification that means lower computational cost and other field requires AMC system to be comprised of as many modulations to increase the flexibility of the system to be used in different application scenarios.

1.3 CONTRIBUTIONS

Following contributions are believed to be concluded from work done:

1. Unsupervised learning has been used for classification in the blind environment. The clustering algorithm is introduced for modulation classification. Density-based OPTICS and partitioning-based k-means are used to classify different order digital modulations.

2. Linear regression is introduced for the classification of the ASK domain of modulation.

3. Method to estimate symbol rate based on the spectrum of the instantaneous phase has been developed.

4. Phase offset from the constellation signature for PSK modulation is developed for the slow and flat fading case.

5. Algorithm based on the local density of the constellation is developed for classification of different orders of ASK, PSK, and QAM.

6. Algorithm based on clustering is implemented and tested on the SDR platform.

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