



# Systematic analysis on the modulation technology

Yuxuan Liu<sup>1</sup>

<sup>1</sup>School of Computer and Communication Engineering, Northeastern University at  
Qinhuangdao, 066099, China  
202212503@stu.neu.edu.cn

**Abstract.** In this paper, the digital modulation methods and their applications are reviewed, which provides a reference for the design and optimization of digital communication systems. Firstly, introduces digital modulation method of ASK, FSK and PSK modulation method and its characteristics. ASK modulation transmits information by changing the carrier wave amplitude, which has the characteristics of simplicity, high bandwidth utilization and weak anti-interference ability. FSK modulation uses carriers of different frequencies to represent digital signals, which has the characteristics of frequency dispersion, strong anti-interference ability and more bandwidth. PSK modulation represents binary state through different phase offset, which has higher bandwidth utilization efficiency and higher data transmission rate than ASK and FSK, but it is sensitive to phase error and noise, and the circuit design is more complicated. And lists some modulation method of mature application, such as PSK and ASK in the TPMS, RFID and vehicle keyless entry application scenarios in the research, and put forward the outlook to the use of composite modulation method.

**Keywords:** Digital modulation, Mature application, Composite modulation

## 1 Introduction

With the continuous development of science and technology and the rise of technologies such as the Internet of Things, the needs of digital communication systems can be meet by converting effectively the analog signals into digital signals. The digital technology application has promoted the progress and optimization of modulation methods. For example, the rapid development of 5G mobile communication technology has put forward higher requirements for modulation methods [1]. 5G networks need to support higher data rates, lower latency, and greater capacity. To meet these needs, new modulation methods such as higher order modulation techniques are introduced to increase the data transmission rate and channel utilization efficiency. Therefore, digital modulation is particularly important.

This paper first introduces the modulation mode of ASK, FSK and PSK, which transmit information by changing the amplitude, frequency and phase of the carrier wave. And introduced their characteristics. The characteristics of ASK are simple, efficient bandwidth utilization and weak anti-interference ability. The characteristics

of FSK are Frequency discreteness, Strong anti-interference ability and require more bandwidth. The characteristics of PSK are higher bandwidth efficiency than ASK and FSK, higher data transfer rates can be achieved, more susceptible to phase errors and noise and more complex circuit design is required than ASK. The second part introduces the mature application of some modulation methods and a compound modulation method.

## 2 Modulation introduction

Under normal circumstances, the strength of the general information signal is weak and cannot be transmitted over long distances. Besides, the influence of environment, external noise, and travel distance will further weaken the signal strength of the message. In order to transmit the message signal to a far place, it is necessary to take advantage of a alto frequency and high-duty carrier signal to mix original message signal of low energy with the carrier signal of high energy to generate a new high-energy signal that can transmit information over long distances, which is the process of modulation. To achieve signal transport, the characteristics of carrier signal (for example amplitude, frequency and phase) need to be changed. So, the modulation is divided into a variety of ways.

### 2.1 Amplitude Keying modulation

Under the control of the binary baseband signal, the carrier can be turned on or off, and the presence or absence of the amplitude of the carrier represents the 1 or 0 of the signals, thus achieving the acquisition of ASK signal [2]. ASK modulation have several characteristics simple, efficient bandwidth utilization and weak anti-interference ability.

At first, the implementation of ASK modulation technology is simple, and only needs to change the amplitude of the signal. This way makes ASK modulation technology is easy to understand and apply. So, ASK modulation is simple. The second point is ASK modulation technology directly uses the amplitude of the signal to represent digital information in the process of signal transmission. Compared with other modulation techniques, ASK can make more efficient use of signal bandwidth resources. Because ASK modulation technology represents digital information by changing the amplitude of the signal, it is more sensitive to noise and interference. In the process of signal transmission, if there is a large interference, it may cause the amplitude of the signal to change, resulting in misjudgment. So, the last characteristic is weak anti-interference ability. Ask was the earliest form of digital modulation, because of it is susceptible to changes in gain. ASK is not widely used in practice. The ASK modulation is shown in figure 1.

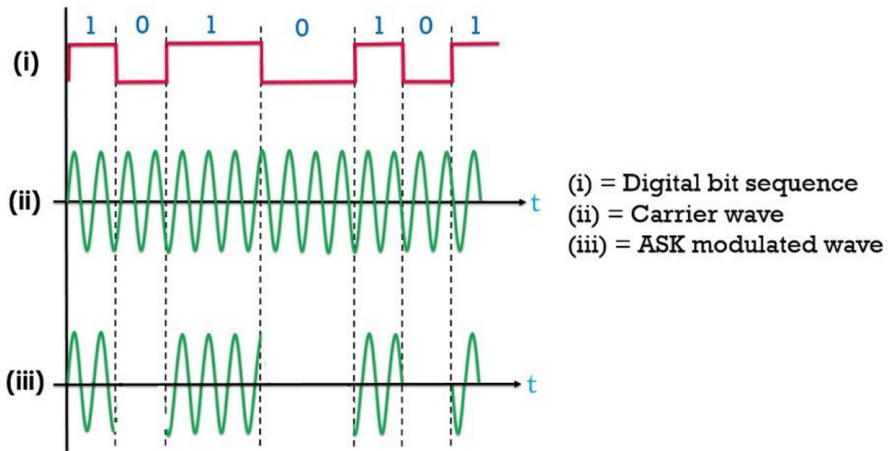


Fig. 1 ASK modulation (Photo/Picture credit: Original)

## 2.2 Frequency Keying modulation

The principle of The FSK modulation technology is based on carrier waveforms at different frequencies to represent digital signals. In general, the low frequency carrier represents the 0, and the high frequency carrier represents the 1. Specifically, FSK modulation technology realizes the conversion and transmission of digital signals by changing the frequency of the carrier. Compared with ASK modulation, FSK modulation has the following advantages: strong anti-interference, high fault tolerance, long transmission distance [3].

At first one of the characteristics of FSK signal is frequency discreteness, the frequency of the carrier signal can only change between several predetermined discrete values. The second point is FSK signal has strong anti-interference ability compared with other modulation technologies. Because the frequency change of FSK signal is obvious, it has less influence on noise and interference signal during transmission, thus improving the reliability of the system. Because of the frequency changes, it caused the spectrum occupancy width of FSK signals is large. FSK digital modulation has better ability of anti-interference and anti-noise, and FSK modulation is generally used to transmit data in the transmission rate below 1200 baud, which is widely used in the transmission of data in the medium and low speed data communication system. The FSK modulation is shown in figure 2.

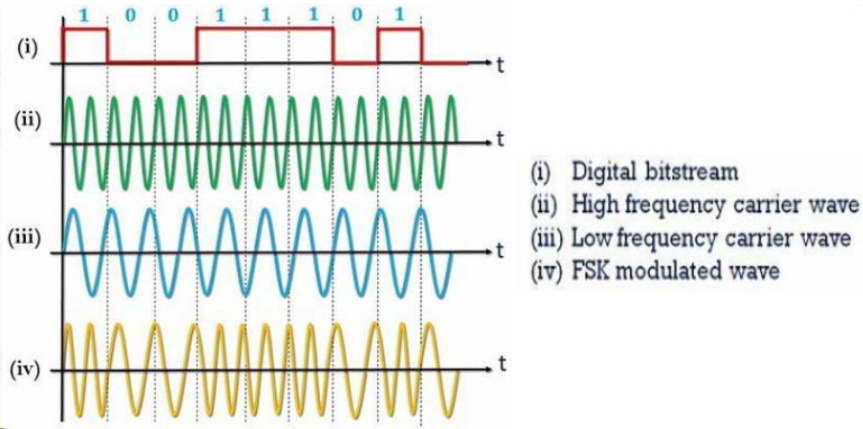


Fig. 2 FSK modulation (Photo/Picture credit: Original)

### 2.3 Phase Keying Modulation

The most basic feature of PSK is that the amplitude and frequency are generally unchanged, and the baseband digital signal is transmitted and distinguished by the phase change of the transmitted carrier. BPSK signals typically use initial phases of  $0^\circ$  and  $180^\circ$  to represent the binary 1 and 0 of the digital baseband signal [4]. This is the principle of PSK modulation. The characteristics of PSK are higher bandwidth efficiency than ASK and FSK, higher data transfer rates can be achieved, more susceptible to phase errors and noise and more complex circuit design is required than ASK. Each modulation scheme has its own advantages and disadvantages, making it suitable for communication scenarios that vary according to factors such as bandwidth efficiency, anti-jamming capability, and implementation complexity. The PSK modulation is shown in figure 3.

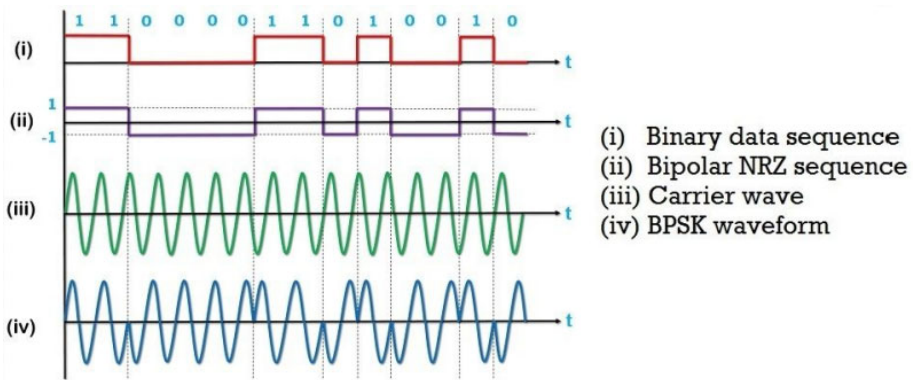


Fig. 3 PSK modulation (Photo/Picture credit: Original)

### 3 Application scenario analysis

#### 3.1 Tire pressure monitoring system (TPMS)

Tire pressure monitoring system can be divided into two kinds from different monitoring methods, respectively are indirect tire pressure monitoring and direct tire pressure monitoring [5]. It's a mature technology born in the 1990s. When in the driving process of the vehicle, if a tire burst occurs, it is easy to occur traffic accidents, and the main cause of the tire burst is the tire pressure problem, in order to monitor the pressure of the tire to prevent a tire burst, TPMS is designed to solve this problem [1]. The system realizes the communication between the tire pressure sensor module (transmitting module) and the tire pressure receiving module through RF wireless signal, and uses 2ask 2psk technology to process the detected data. It can monitor the pressure and temperature of the tire from time to time, give timely alarm to the high pressure, low pressure and air leakage of the tire, and give early warning to the possible tire burst accident with the cooperation of the tire temperature, and enhance the safety of the car at high speed.

#### 3.2 Radio frequency identification (RFID)

It is a technology for wireless identification and item tracking, and the working frequency band is 125kHz, which is often used in pet identification, logistics management, access control [3]. RFI can automatically identify and track items through radio wave communication with reader-writer, which can improve the efficiency and accuracy of supply chain management. According to the advantages of FSK (Strong anti-interference High fault tolerance and long transmission distance), the author chose the FSK modulation mode to increase the reliability and stability of the tag signal and increase the effective read-write distance with the reader-writer and designed a low-frequency RFID tag chip that receives ASK signals and sends FSK modulated signals. The label can meet the needs of animal labeling, logistics management and other highly intrusive scenarios.

In license plate recognition, there are two main ways to apply RFID technology: one is to use RFID tags to replace traditional license plate recognition methods, and the other one is to combine RFID technology with traditional license plate recognition to improve efficiency [6]. The advantage of this method is that the recognition accuracy is high, the speed is fast, and it is not affected by factors such as environment and light. By installing RFID tags, and then using a reader to read the RFID tag of the license plate, can obtain the unique identity information of the vehicle. People can realize real-time monitoring of vehicles by using RFID tags. Such as record vehicle entry and exit time, location, speed and other information for subsequent data analysis and processing.

Design of library intelligent management system based on RFID. Applying RFID technology to the design of intelligent library management department can realize the function of automatically returning books, facilitate the intelligent and efficient management of the library, and reduce the workload in the library [7]. Its principle is

to use the reader, using the antenna transmission way, to complete the unified transmission of a certain frequency of RF signals, when the RFID signal identification area appears electronic tags, electronic tags can be successfully activated, and the formation of the corresponding induced current. Subsequently, the electronic tag sends the RF signal to the reader with the help of the antenna, and the reader decodes and processes the electronic tag information with the help of modulation and demodulation, and sends and transmits it to the host system, and the host system processes the data uniformly.

### **3.3 Remote Keyless Entry (RKE) and Passive Keyless Entry (PKE)**

RKE and PKE are two core systems in the car access control system. RKE system eliminates the need for people to touch the key with their hands, insert the key into the lock hole, and turn the key. When people hold items in their hands, they can complete the unlocking/locking (unlocking/foraging) control of the vehicle by simply pressing the corresponding button, which provides users with great convenience. The emergence of the PKE system is to further eliminate the operation of pressing the key button, only the person with the legal PKE key, when the person approaches the vehicle to a certain range, the system automatically identifies the key, and then performs the corresponding control according to the user's operation, and its convenience is further improved [8]. The author starts with the 2ASK optimal receiver, and improves the anti-jamming ability of RKE system by analyzing its principle and partial processing of baseband signal, improved anti-interference performance, can be better applied in intelligent development.

Application of PKE technology in smart home access control system. At present, there are many identification methods of smart door locks, such as magnetic card, fingerprint recognition, iris recognition. These methods are active, requiring users to take the initiative to swipe cards or brush fingerprints and other operations to complete the identification, and the use of PKE does not need this operation, as long as it is carried and entered the identification range to complete the identification process [9]. The identification method is more secure than the traditional unlocking method, and can be linked with other networked furniture to provide users with a more intelligent life experience.

### **3.4 Transmitter/receiver for car burglar alarm system:**

The transmitter is placed inside a vehicle parked outside, and the receiver is placed inside the home. As the vehicle leaves the area, the distance between the transmitter and receiver increases, causing the power of the signal received by the receiver to decrease [10]. Once the signal power falls below the set threshold, the circuit will trigger an audible alarm, thus achieving an anti-theft function to some extent. In addition, this circuit can also be used for other alarm functions, such as to prevent the loss of USB flash drives or to prevent children from going missing.

### 3.5 Composite modulated signal

With the rapid development of national defense space TT&C technology, the modulation methods of signals have become complex and diverse, and composite modulated signals have attracted much attention because of their secondary and above modulation characteristics, which has important research value in both military and civilian applications [11]. Composite modulated signals have attracted much attention because of their secondary and above modulation characteristics. In order to develop the technology for military and civil use, the author proposes and realizes a variety of composite modulation classification and recognition algorithms, and designs related parameter estimation and demodulation algorithms for six types of composite modulation signals.

Locating submarine DC cable faults, because the damage of submarine cable will lead to a long time of power failure, resulting in frequent accidents, it is important to find the fault source quickly [12]. However, the existing spread spectrum time domain reflectometry method has low test efficiency and accuracy due to its limited range of range due to the symbol duration. By using a hybrid modulation, m sequences with different symbol durations are multiplied and modulated through sinusoidal signal by 2PSK, mixing signals with rich fault information are obtained. The blind area of distance measurement can be reduced and the disadvantages of existing methods can be overcome.

## 4 Conclusion

In shortly, future modulation methods will continue to develop in the direction of high speed, high efficiency, low energy consumption and reliability to meet the growing communication needs and the requirements of technological development. At the same time, with the emergence of emerging technologies, there may be more innovative modulation methods to adapt to the needs of different application scenarios. When the unknown parameters are more and more complex, the calculation amount will become very large, and the processing difficulty will increase. In order to deal with more complex situations and obtain better information, composite modulation will be more needed. In the future, more advanced methods will be needed to determine the best type of modulation required.

## References

1. Xiu Chang Qin. Research and design of tire pressure Monitoring System (TPMS). University of Electronic Science and Technology of China, 2014.
2. Huynh-The T, Pham Q V, Nguyen T V, et al. Automatic modulation classification: A deep architecture survey[J]. IEEE Access, 2021, 9: 142950-142971.
3. Qi M. Design and implementation of low frequency RFID tag based on FSK. Guilin University of Electronic Technology, 2023.
4. WeiZhe Q. Digital communication signal simulation analysis technology based on PSK modulation. Telemetry and remote control, 2023, 44(01): 57-63.

5. Li L. Research on tire pressure monitoring system based on radio frequency technology. Hebei University of Technology, 2015.
6. YaQi Y, Feng F. Research and application of license plate recognition technology based on RFID. *Internet of things technology*, 2024, 14(04): 9-11.
7. ShengBo G, RuiYong W. Design and implementation of university intelligent library system based on RFID technology. *Information recording material*, 2022, 23(05): 135-137.
8. WeiDong H. Study of automotive rke/pke system with anti-jamming, security access and smart development. Shanghai Jiao Tong University, 2014.
9. XiaoJun Z. The Research and Design of Intelligent Home Access Control Based On PKE. Hunan University, 2018.
10. Yeung A T, Tang W. ASK transmitter/receiver for automotive burglar alarm systems. *Chinese integrated circuit*, 2013, 22(Z1): 83-85.
11. CunZhu Z. Research and implementation of classification and recognition technology for composite modulation signals. University of Electronic Science and Technology of China, 2023.
12. LongLei B, DaoPing F, Bo L, et al. Research on Fault Location Method for Submarine DC Cable Based on Mixed Modulation. *Proceedings of the CSEE*, 2024, 1-9.

**Open Access** This chapter is licensed under the terms of the Creative Commons Attribution-NonCommercial 4.0 International License (<http://creativecommons.org/licenses/by-nc/4.0/>), which permits any noncommercial use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license and indicate if changes were made.

The images or other third party material in this chapter are included in the chapter's Creative Commons license, unless indicated otherwise in a credit line to the material. If material is not included in the chapter's Creative Commons license and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder.

