Original Research Article

Construction of an Experimental Device for Military Communication Using Binary Amplitude Shift Keying

ABSTRACT

Aims: To address the core requirement for military communication systems—ensuring "timely, accurate, confidential, and secure" communication—this study aims to overcome the limitations of traditional amplitude modulation (AM) methods by developing a modern experimental device using Binary Amplitude Shift Keying (BASK) modulation.

Study design: Traditional military communication systems rely on AM modulation due to its simplicity and ease of implementation. However, AM is susceptible to noise, suitable only for long-wave transmissions (e.g., AM radio), and struggles to integrate with modern technologies like 4G and 5G. To address these challenges, this study explores the mathematical foundation and system design of BASK modulation and demodulation.

Methodology: The research investigates the mathematical principles of BASK, designs the system architecture for BASK modulation and demodulation, and develops an experimental device to validate the performance of the BASK-based communication model.

Results: The study successfully developed an experimental device that demonstrates the feasibility of using BASK modulation for military communication. The device provides a platform for practical testing and verification of the BASK model, laying the groundwork for further advancements.

Conclusion: This research provides a foundation for modernizing military communication devices. By overcoming the limitations of traditional methods and facilitating the integration of advanced technologies, the proposed device meets the stringent requirements of military environments.

Keywords: AM radio, Binary Amplitude Shift Keying, Modulation, Demodulation

1. INTRODUCTION

In military communication systems, ensuring "timely, accurate, confidential, and secure" communication is a critical requirement. Traditional communication methods, such as AM modulation, while technically simple, are highly susceptible to noise and incompatible with modern technologies like 4G and 5G. AM modulation is primarily used for long-wave transmissions, such as AM radio, but falls short of meeting the requirements for security and transmission efficiency in military environments.

On the other hand, ASK modulation has demonstrated significant advantages in enhancing noise immunity and adapting to new technologies. ASK modulation encodes digital signals using various amplitude levels, ranging from Binary Amplitude Shift Keying with two amplitude levels to Multi-Level Amplitude Shift Keying (MASK) with multiple levels, optimizing bandwidth usage and improving transmission efficiency.

The ASK modulation method has been widely applied in various systems, from civilian applications such as keyless entry systems, RFID tags, and short-range wireless communication, to military applications like Morse code telegraphy, remote monitoring, and control systems. Notably, ASK has proven effective in transmitting data securely and reliably under extreme conditions.

Fig.1. Remote Keyless Entry System

Fig.2. RFID System for Warehouse Management

Fig.3. NFC Short-Range Wireless Communication Device

This paper focuses on researching and developing an experimental device for military communication using BASK modulation. Specifically, we study the mathematical foundation and design the system architecture for BASK modulation and demodulation. Additionally, we develop an experimental device to validate these modulation models in real-world environments.

The experimental device serves as a tool for verifying the performance of BASK modulation models. Furthermore, it provides a foundation for the development of communication systems that meet the stringent requirements of military operational environments.

2. BINARY AMPLITUDE SHIFT KEYING MODULATION

2.1. Mathematical Foundation

- BASK modulation is a technique that uses each bit of the input digital signal to modulate the amplitude of the carrier wave with two levels. BASK modulation is the process of shifting the signal's spectrum from the low-frequency domain to the high-frequency domain to match the transmission channel, enabling long-distance communication over mediums such as wires, optical fibers, or air. BASK modulation is performed at the BASK transmitter.

-The BASK modulation method has the following signal forms:
The input bit sequence s(t). Assume:

$$s(t) = \{0\ \ 0\ \ \ 1\ \ 1\ \ 0\ \ 1\ \ \ 0\ \ 0\ \ 0\ \ 1\ \ \ 0\} \tag{1}$$

The binary NRZ encoded signal is:

$$b(t)=A.s(t)=\begin{cases} A & s(t)=1 \\ 0 & s(t)=0 \end{cases} \tag{2}$$

The carrier signal is:

$$x(t) = cos(2\pi f_c t) \tag{3}$$

The BASK modulated signal is:

$$y(t) = A.\ s(t).cos(2\pi f_c t) \tag{4}$$

- After applying the Fourier transform, we obtain:
The spectrum of the signal b(t) is:

$$B(f)=FT\{b(t)\}=\int_{-\infty}^{+\infty} b(t).e^{-j2\pi ft}dt \tag{5}$$

The spectrum of the signal y(t) is:

$$Y(f)=FT\{y(t)\}=\int_{-\infty}^{+\infty} y(t).e^{-j2\pi ft}dt = \int_{-\infty}^{+\infty} b(t).cos(2\pi f_c t).e^{-j2\pi ft}dt$$

$$Y(f)=\frac{1}{2}\int_{-\infty}^{+\infty} b(t)(e^{j2\pi f_c t}+e^{-j2\pi f_c t})e^{-j2\pi ft}dt$$

$$Y(f)=\frac{1}{2}\int_{-\infty}^{+\infty} b(t).e^{-j2\pi(f+f_c)t}dt+\frac{1}{2}\int_{-\infty}^{+\infty} b(t).e^{-j2\pi(f-f_c)t}dt$$

$$Y(f)=\frac{1}{2}.B(f+f_c)+\frac{1}{2}.B(f-f_c) \tag{6}$$

Comments:
The signal b(t) has a low frequency but a wide spectrum.

The spectrum of the BASK signal consists of two components: one around $+f_c$ and the other around $-f_{c.}$

The spectrum structure of the BASK signal is concentrated around the carrier frequency $\pm f_c$ and depends on the bandwidth of the encoded signal b(t).

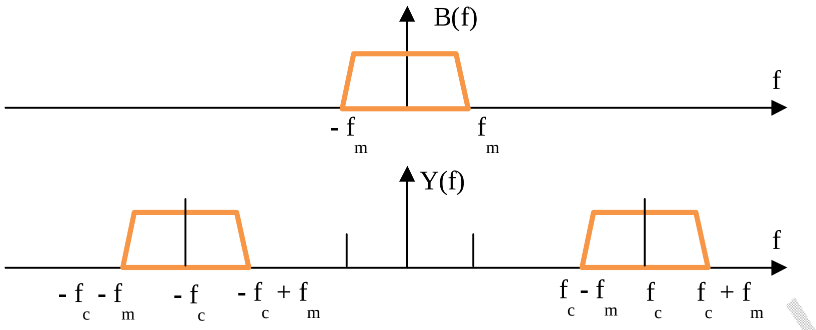

Fig.4. Spectrum of the BASK Signal

2.2. Modulation Principle

The structure diagram of the BASK modulator is shown in Figure 5.

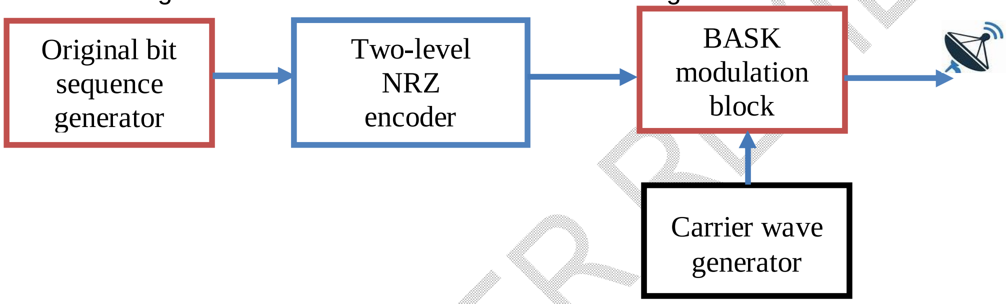

Fig.5. Structure Diagram of the BASK Modulator

Bit Sequence Generator: Bit Sequence Generator: Generates the input bit sequence that represents the information to be transmitted, using a pseudo-random binary sequence (PRBS).

NRZ Encoder: Converts the input bit sequence into a Non-Return-to-Zero (NRZ) encoded signal. Each bit is represented by a voltage level.

Carrier Signal Generator: Produces a high-frequency oscillation, with the carrier frequency tunable by the user within the range of 100 MHz to 1 GHz. No significant frequency shift is observed from the desired carrier frequency, as the carrier wave generator maintains stability within an acceptable tolerance.

BASK Modulation Block: A switch controlled by the NRZ signal, modulating the carrier's amplitude with two high and low levels corresponding to the two bit states. The BASK signal has two amplitude levels, with the same frequency as the carrier, enabling long-distance signal transmission.

3. BINARY AMPLITUDE SHIFT KEYING DEMODULATION

3.1. Mathematical Foundation

- BASK demodulation is the process of recovering the original digital signal from the BASK-modulated signal. The demodulation process involves determining the amplitude levels of the signal and mapping them back to the corresponding binary bit sequence in order to regenerate the original information. BASK demodulation is performed at the BASK receiver.

- The BASK demodulation method involves the following signal forms:

The received signal at the BASK receiver with noise N(t) is:

$$r(t)=C(t).\cos(2\pi f_C t)+N(t) \tag{7}$$

The base carrier signal: $\cos(2\pi f_c t)$

The result of multiplying the base carrier signal by the received signal:

$$r(t).\cos(2\pi f_C t)=C(t).(\frac{1}{2}+\frac{1}{2}\cos(4\pi f_C t))+N(t).\cos(2\pi f_C t) \tag{8}$$

Comments:

The spectrum of the signal consists of three components:

The low-frequency component corresponding to the envelope C(t), which represents the original information.

The high-frequency component with frequencies at fc and $2.f_c$.

To recover the original signal, a low-pass filter is needed to remove the high-frequency components and retain the low-frequency ones. The accuracy of recovering the original signal depends on the carrier synchronization technique, noise processing, and NRZ decoding.

3.2. Demodulation Principle

The structure diagram of the BASK demodulator is shown in Figure 6.

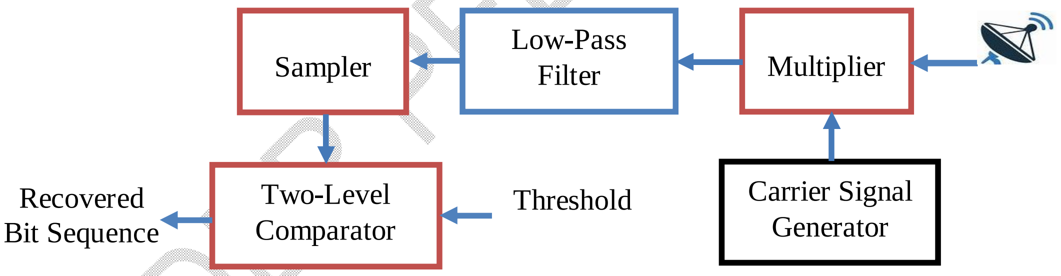

Fig.6. Block Diagram of the BASK Demodulator

Carrier Signal Generator: Generates a harmonic carrier wave with a fixed frequency.

Multiplier: Multiplies the noisy BASK modulated signal with the carrier wave, producing a new signal containing multiple spectral components: a slowly varying amplitude envelope component, high-frequency components at f_c, and $2f_c$.

Low-Pass Filter: Removes high-frequency components, retaining only the amplitude envelope of the BASK modulated signal. The cutoff frequency of the Low-Pass Filter (LPF) is adjusted in proportion to the selected carrier frequency, ensuring optimal signal filtering.

Sampler: Samples the signal after filtering, converting the continuous signal into a discrete signal.

Two-Level Comparator: Compares the amplitude of the sampled signal with a specific threshold. If the amplitude exceeds the threshold, the signal is determined to represent bit '1'; otherwise, it is identified as bit '0'. The comparator output forms a bit sequence that corresponds to the original transmitted bit sequence.

4. EXPERIMENTAL EQUIPMENT

4.1. Equipment Introduction

- Figure 7 illustrates the front panel structure and the input/output connectors of the BASK modulation experimental device.The experimental device for BASK modulation, as depicted in the figure, consists of four key modules:

Bit Sequence Generator: This module generates a sequence of binary bits (S), serving as the input digital data for the modulation process.

Two-Level NRZ Encoder: Converts the binary bit sequence (S) into an NRZ format signal (B), suitable for modulation.

Carrier Wave Generator: Produces a harmonic carrier wave (X) with a fixed frequency, used for modulating the input signal.

BASK Modulator: Combines the carrier wave (X) and the NRZ signal (B) to produce the BASK modulated signal (Y), which contains amplitude variations corresponding to the input digital data.

This device provides a hands-on platform for studying and analyzing the fundamental principles of BASK modulation.

Fig.7. Experimental Equipment for BASK Modulation

The BASK demodulation experimental device, as illustrated in Figure 8, consists of five main modules:

Carrier Wave Generator: Generates the carrier wave (X) required for the demodulation process.

Signal Multiplier: Multiplies the received BASK modulated signal (Y) with the carrier wave (X) to produce a signal containing various frequency components ($X{\cdot}Y$).

Low-Pass Filter: Eliminates high-frequency components from the mixed signal, preserving the low-frequency component of the amplitude envelope (B).

Sampler: Converts the filtered continuous signal into discrete samples (Bs) for further processing.

Two-Level Comparator: Compares the amplitude of the received signal (Bs) with a predefined threshold to determine the corresponding bit sequence (S) for the transmitted data. The threshold can be adjusted via the "Threshold" potentiometer.

Additionally, the device includes various input and output ports (X, Y, $X{\cdot}Y$, B, Bs, S) to facilitate signal observation and analysis at different stages of the demodulation process.

- Figure 8 illustrates the front panel structure and the input/output connectors of the BASK demodulation experimental device.This experimental device provides a practical platform for understanding and experimenting with the fundamental principles of BASK demodulation.

Fig.8. Experimental Equipment for BASK Demodulation

4.2. Experimental Results

- The results of the BASK preparation are presented in Figure 9.

Assume a binary input sequence: $s(t) = \{1\ 0\ \ 1\ \ 1\ \ 0\ \ 0\}$

The NRZ-encoded signal exhibits two voltage levels: 0V and 1V.

The carrier wave is a harmonic oscillation with a high frequency.

The output BASK-modulated signal has two amplitude levels corresponding to the binary input. It retains the carrier wave frequency, allowing effective transmission over long distances.

The constellation diagram consists of two points (stars) on the I-axis at positions 0 and 1. The I-axis represents the real component corresponding to the in-phase carrier wave. The Q-axis represents the imaginary component, corresponding to the quadrature-phase carrier wave.

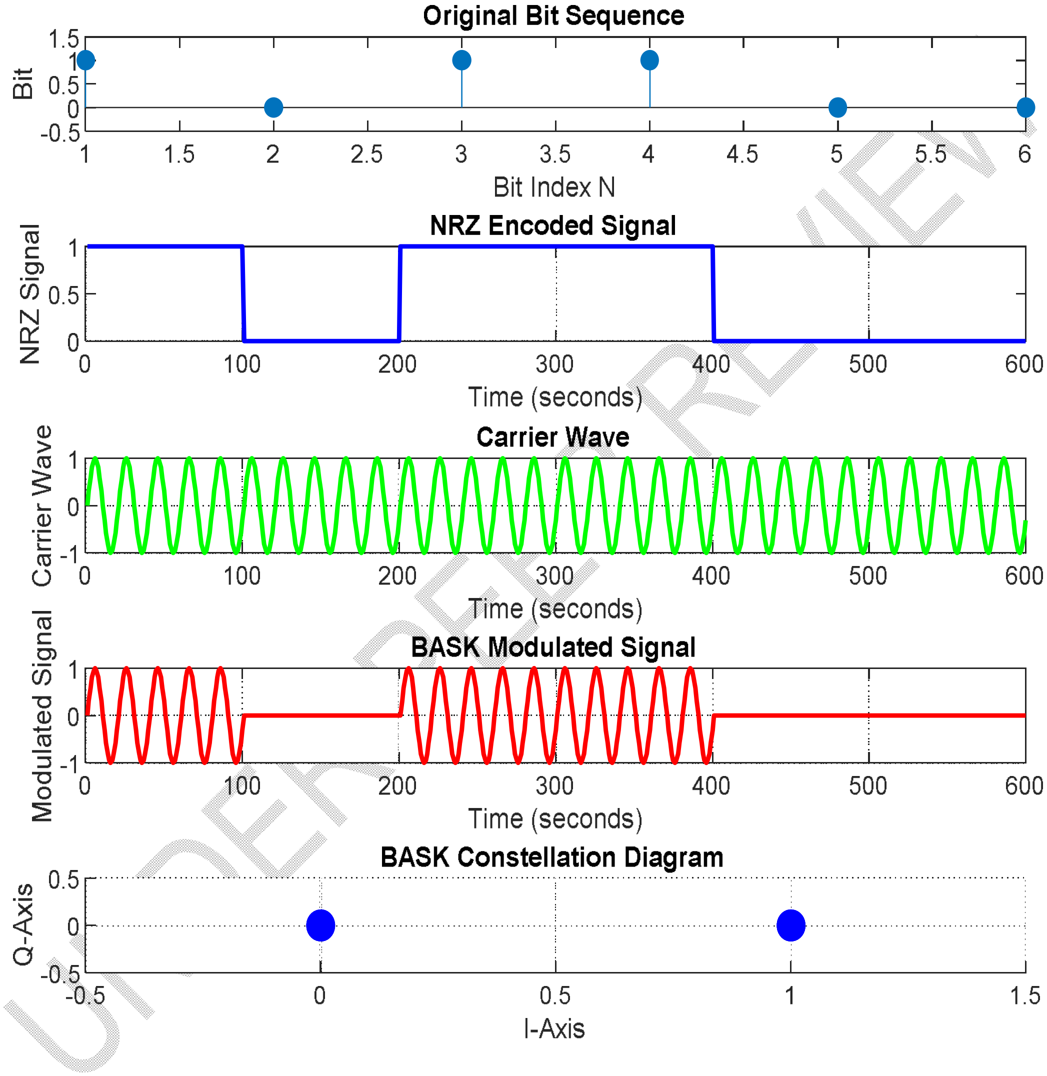

Fig. 9. Graphs of Signals in BASK Modulation

The results of the BASK demodulation are shown in Figure 10. The modulated BASK signal, which contains noise at the receiver input, is multiplied by the carrier wave, generating a new signal with multiple frequency components: the slowly varying envelope component, high-frequency components f_c, and $2f_c$. After passing through a filter, the high-frequency components are removed, and the envelope component is retained for sampling. The samples are compared to a threshold level of 0.3V. When the sample amplitude is greater than the threshold, the signal is identified as bit '1.' If the sample amplitude is less than or equal to the threshold, the signal is identified as bit '0.' The comparison results produce a bit stream that corresponds to the original bit stream.

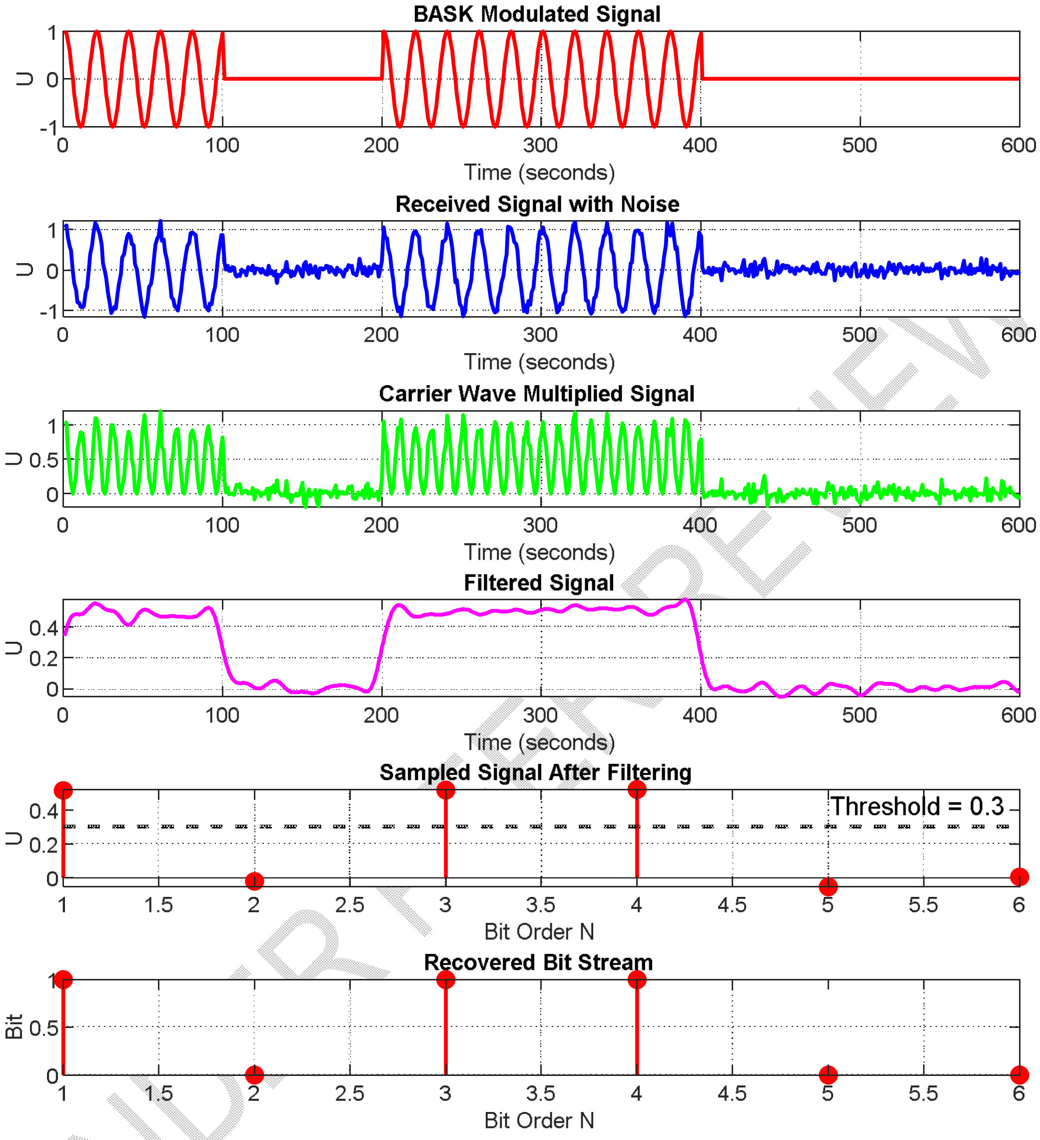

Fig. 10. Graphs of Signals in BASK Demodulation

5. CONCLUSION

This paper has investigated and developed an experimental device for military communication using the Binary Amplitude Shift Keying modulation method. The study evaluates the characteristics and applications of this method in information security and safety. The research results confirm that BASK modulation offers advantages in enhancing noise resistance and compatibility with modern communication technologies such as 4G and 5G while maintaining high performance in the harsh environments of military communication systems. The developed BASK modulation and demodulation system not only provides a reliable experimental tool for testing this modulation scheme but also lays a solid foundation for the development of modern military communication devices and systems that fully meet the stringent requirements for security, safety, and effective information transmission in combat environments.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

The author(s) hereby declare that no generative AI technologies, such as Large Language Models (e.g., ChatGPT, COPILOT) or text-to-image generators, were used in the writing or editing of this manuscript.

COMPETING INTERESTS: The authors have declared that no competing interests exist.

REFERENCES

Richard W. Middlestead. (2017). Amplitude Shift Keying Modulation, Demodulation, and Performance. In Digital Communications with Emphasis on Data Modems: Theory, Analysis, Design, Simulation, Testing, and Applications, pp. 227–250. IEEE. DOI: 10.1002/9781119011866.ch6.

Adeleke, O. A., & Abolade, R. O. (2012). Modulation Methods Employed in Digital Communication: An Analysis. IJECS-IJENS, 12(3).

Bhambare, R. (2013). A Survey on Digital Modulation Techniques for Software-Defined Radio Applications. IRACST, 3.

Africa, A., & Castillo, J. J. M. (2020). Design of an ASK Modulation Digital Signal Conversion System.

Bala, D., Waliullah, G. M., Islam, N., Abdullah, I., & Hossain, M. A.

Ahmadi, M. M., Pezeshkpour, S., & Kabirkhoo, Z. (2021). A High-Efficiency ASK Modulated Class-E Power and Data Transmitter for Medical Implants. IEEE Transactions on Power Electronics, 37(1), 1090–1101.

Sasmita. (2018). Coherent Binary Amplitude Shift Keying. Electronic Post.

Ahommed, R. (2023). Amplitude Shift Keying. Department of Computer Science & Engineering, Southeast University.

Liu, P., Gao, T., Zhao, R., Mao, Z., & Zhu, Q. (2022). A Novel Modulation and Demodulation Method Based on Binary Frequency Shift Keying for Wireless Power and Data-Parallel Transmission. Micromachines, 13(9), 1381. DOI: 10.3390/mi13091381.

Zhang, Y., Li, X., & Wang, J. (2023). Photonic Generation of ASK Microwave Signals with SSB Format. Photonic Network Communications, 45(1), 75–85. DOI: 10.1007/s12200-023-00075-2.

Wang, H., & Chen, L. (2020). Design of an ASK Modulation Digital Signal Processor for Communication Systems. ARPN Journal of Engineering and Applied Sciences, 15(1), 83–88.

Li, J., & Zhao, S. (2023). On Rate Performance of M-ary Amplitude Shift Keying Compact Ultra Massive Array Systems for Massive Connectivity. Electronics Letters, 59(10), e13077. DOI: 10.1049/ell2.13077.

Zhou, Y., & Xu, J. (2023). Generation of Frequency-Shift Keying (FSK) and Amplitude-Shift Keying (ASK) RF Signals by Diode-Tuned Fourier Domain Mode-Locked Opto-Electronic Oscillator. Optics Express, 32(22), 39643–39655. DOI: 10.1364/OE.32.039643.