DIGITAL SIGNAL PROCESSING ORIENTED ELECTRONIC COMMUNICATION ENGINEERING APPLICATIONS AND PRACTICES

Qinghe Wang*

- Jiangsu College of Tourism, Yangzhou, Jiangsu, 225000, China
- E-mail: qinghewang202388@163.com

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ABSTRACT

This paper first describes the applications of digital signal processors in software radio, speech compression coding, modems and GPS systems, demonstrating the versatility of digital signal processors in practical communication systems. Next, digital signal processing oriented electronic communication practices are presented in the system design section to design high performance communication systems for specific communication needs and environmental conditions. The digital signal processing platform used in the platform architecture is optimized for signal processing and data transmission. The BER is 0.008% when the signal-to-noise ratio is -10 dB. The time complexity of digital signal processing is 7.2 ms when the number of communication nodes is 1000. It shows that digital signal processing oriented electronic communication engineering is important for improving the performance, reliability and efficiency of communication systems.

KEYWORDS

Digital signal processing; speech compression; GPS system; electronic communication; signal-to-noise ratio

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1. INTRODUCTION

The research on the application and practice of electronic communication engineering oriented to digital signal processing is at the forefront of the current scientific and technological development, integrating the latest achievements of electronic engineering, communication technology and computer science [1]. With the rapid development of digital technology, digital signal processing has become the core technology in the field of electronic communication, which plays a key role in many aspects such as speech, image processing, wireless communication and data compression [2]. The rapid progress in this field, especially the breakthroughs in mobile communication, satellite communication and network technology, has brought revolutionary changes to electronic communication engineering [3]. The high efficiency, flexibility and powerful functions of digital signal processing technology provide the possibility of processing a large number of complex communication signals, and at the same time bring new challenges, such as the need for high-speed signal processing, signal quality assurance and the implementation of complex algorithms [4]. Therefore, studying the application and practice of digital signal processing in electronic communication engineering is not only crucial for the development of the theory, but also has a far-reaching impact on practical engineering applications [5]. With the rise of the Internet of Things, smart devices and 5G communication technology, the research and exploration of this field will be more urgent, foreshadowing the future development direction and application prospects of communication technology [6].

The density matrix of subsystems in reacting complexes is discussed by Nalewajski, R. F and is used to describe the entanglement phenomena occurring in donor-acceptor systems including molecular fragmentation and electronic communication [7]. Han, D et al. activated the molybdenum disulphide MoS2 by doping it with palladium and achieved a phase transition to the stable 1T phase. The study was also verified using Raman spectroscopy. The prepared Bi/Pd-MoS2 catalysts exhibited excellent electrochemical hydrogen precipitation performance in acidic medium [8]. Toyoshima, M discussed the concept of utilizing smaller and less power consuming on-board devices for broadband and high capacity communications. This technique can provide more efficient communication in space communication and has a wide range of applications [9]. Zhang, L et al. proposed that conventional wireless communication usually requires digital-to-analog conversion and frequency mixing to transmit digital information to different users at different locations. However, spatio-temporal coded digital metasurfaces can encode spatio-temporal coding matrices over multiple channels and directly transmit digital information to multiple users at the same time without the need for complex processing [10]. Tan, M. et al. introduced an optical signal processing technique that achieves extremely high performance, including high bandwidth and low energy consumption. This optical signal processor can process 17 Terabits/s of data, is capable of processing 400,000 video signals simultaneously, and performs 34 different image processing functions such as object edge detection, edge enhancement, and motion blur processing [11]. He, X et al. stated that although power electronics and communication electronics are often regarded as two different branches of the electrical engineering field. However, both are based on electromagnetic theory. In addition, electricity is considered as the most common material-based information carrier. Therefore, power electronics and communication electronics can be considered together to find new applications and approaches [12]. Huang, C et al. proposed a new approach to construct highly parallel, ultrafast neural networks using photonic devices to process optical signals in the analog domain, thus reducing the need for digital signal processing circuits. A silicon photonic electronic neural network was reported for solving the fiber nonlinearity compensation problem in submarine fiber optic transmission systems [13]. Niu, Z et al. described the architecture of this communication system using the microwave band to provide multiple signal carriers that are converted to 220GHz channels, thus reducing the need for high sampling rate analog-to-digital converters. The system consists of a set of 220 GHz solid-state transceivers including two signal carriers and two basebands to support 4 GSPS analog-to-digital converters. A 16QAM modulation is used [14].

Digital signal processors are used to process and optimize signals to improve the performance of communication systems. This paper firstly describes the application of digital signal processor in communication engineering to realize flexible radio communication systems through digital signal processing so that they can adapt to different communication standards and spectrum requirements. The application of digital signal processing in voice coding can help to achieve efficient data compression and transmission in order to deliver high quality voice communication with limited bandwidth. Modems are key components in communication systems and digital signal processing helps to improve the performance of modems to ensure reliable data transmission. In digital signal processing oriented electronic communication practices, system design and platform architecture are carried out to ensure effective application of digital signal processing in practical communication engineering.

2. APPLICATION OF DIGITAL SIGNAL PROCESSOR IN COMMUNICATION ENGINEERING

2.1. APPLICATIONS IN SOFTWARE RADIO

The application of software radio in communication, especially in the 3rd generation mobile communication has become more and more the focus of research. Digital signal processor hardware technology and its algorithms are precisely the key to the realization of software radio, software radio system flexibility openness and tolerance and other characteristics, mainly through the signal processor as the center of the general hardware platform and software to achieve [15-16]. Figure 1 shows the software radio system framework, mainly to complete the radio station internal data processing modulation and demodulation and coding and decoding work. Due to the radio internal data flow, filtering frequency conversion and other processing operations more often, must use high-speed real-time parallel digital signal processor module, or special integrated circuits in order to meet the requirements. To complete such a difficult task, must require hardware processing speed increases, chip capacity expansion, while requiring algorithms for the processor optimization and improvement.

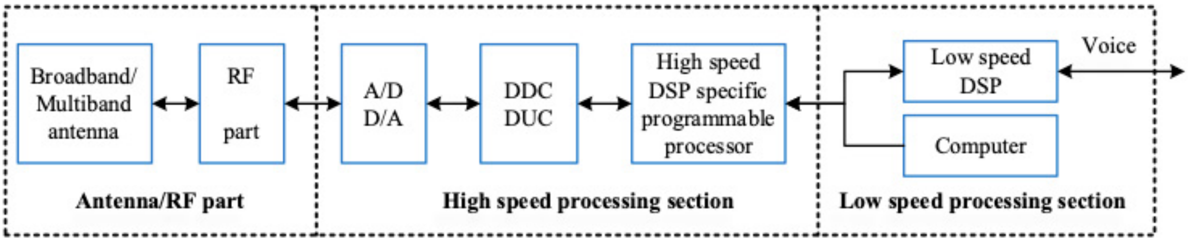

Figure 1. Software radio system

2.2. APPLICATIONS IN SPEECH COMPRESSION CODING

2.2.1. PRINCIPLES OF COMPOSITION

The purpose of speech data compression is to be able to obtain high quality speech effects at the lowest possible transmission rate. That is, it is desired that the speech signal can be transmitted in a channel with a more observable bandwidth with little or as little degradation in the quality of the speech as possible [17]. Speech coding systems early used waveform coding methods, also called waveform coding which essentially follows the Nyquist sampling theorem, adaptive ability to synthesize better speech quality [18]. But the coding rate is high, the coding efficiency is very low and parametric coding is different from waveform coding efficient coding method, is the mechanism of speech generation is mainly on the extracted speech signal characteristics of the parameters of the coding, can achieve a very low coding rate. But can only achieve the effect of synthesized speech, voice quality is not as good as waveform coding for voice processing, the higher the compression rate, the more complex the coding algorithm, real-time compression is not possible to use logic circuits to achieve, but also will not be used to achieve a large volume of slow and high-cost microcomputer. The digital signal processor is a suitable choice, Figure 2 for the composition of the principle of speech coding, the use of DSP to develop embedded voice coding and decoding system, it is one of the popularity of the current research. In the network conference voice communication monitoring systems and other areas are important components, the use of digital signal processors not only for the application of voice compression algorithms provide a broad prospect, and make the system design becomes simple reliability is also greatly improved.

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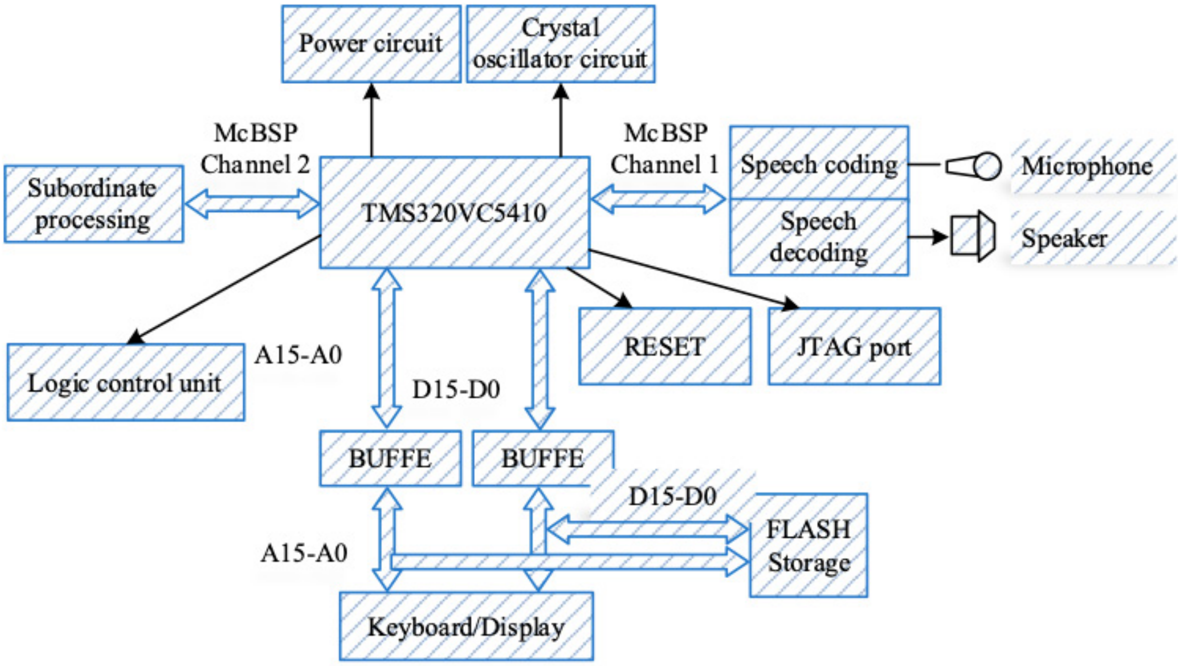

Figure 2. Components of speech coding

2.2.2. SIGNAL OPERATING MODES

There are four modes of operation during communication, including:

1. The default mode after power-up or reset is the single-frequency signal mode, with a default value of zero in the frequency control word register [19]. The default value after power-up or reset defines a safe no-output state that produces a 0 Hz, 0 phase output signal. The default zero amplitude setup mode outputs from both the I and O digital-to-analog converters are DC, with an amplitude corresponding to a medium output current. The user must program some or all of the 28 registers to obtain the desired output signal. The value of the frequency control word is determined by the following equation:

$$FTW = (DOF*2N)/*SYSCLK \quad (1)$$

Where N is the phase accumulator, in this case 48 bits, the frequency is expressed in Hz, and the frequency control word, FTW, is a decimal number. Once a decimal number has been calculated, it must be rounded to the nearest whole number and then converted to binary format. The basic sine wave DAC output frequency ranges from DC to 1/2 system clock. The phase is continuous as the frequency changes, meaning that the new frequency uses the last, phase of the old frequency as the starting phase.

2. When the frequency shift keying mode is selected, the output frequency of the DDS is the value of frequency control word register 1 or frequency control word register 2. The selection of the frequency register is controlled by the logic level terminal PIN29. When logic is low on PIN29, select F1, frequency control word

1, and when logic is high, select F2 frequency control word 2. Frequency changes are phase-continuous and almost instantaneous.

3. CHIRP mode is also known as pulse FM. Pulse FM can be used with any sweep, but most Chirp systems use a linear FM sweep. This is a spread spectrum modulation that allows for processing gain. The user-definable frequency range FTW1~FTW2, duration, frequency resolution, and sweep direction can be internally generated linear, monitored and managed by the electric frequency manager, or externally programmed to generate a nonlinear sweep.3GN00LD can be pulsed or continuous wave. Non-linear sweeping is achieved by varying the time step slope counter, and the frequency step delta frequency word to produce different slopes. delta frequency control word is a binary complement, positive or negative, which defines the direction of the CHIRP mode sweep. If the DELTA frequency control word is negative, the highest bit goes high. If the DELTA frequency control word is negative, the highest bit is a high level, the frequency is scanned from FTW1 to the negative direction, and the frequency is decreasing.

2.3. APPLICATIONS IN MODEMS

In a modem, a digital signal processor is used to perform tasks such as modulation and demodulation, adaptive equalization, and echo cancellation. Figure 3 shows the operating principle of the demodulator, TMS320C25 has a large storage space and rich internal resources, so it can support a variety of standard algorithms in the classic modem, synchronization and timing is the use of the phase discriminator road filter voltage-controlled oscillator and other components of the phase-locked loop. The DS has a very high precision internal programmable timer sound quite interface circuit TLC32044c, and the rate can be fine-tuned with the program 14-bit A/D and D/A converter. Therefore, the above mentioned by the DSP and other devices constitute the modulation and demodulation scheme, all operations, including timing and synchronization can be achieved with software.

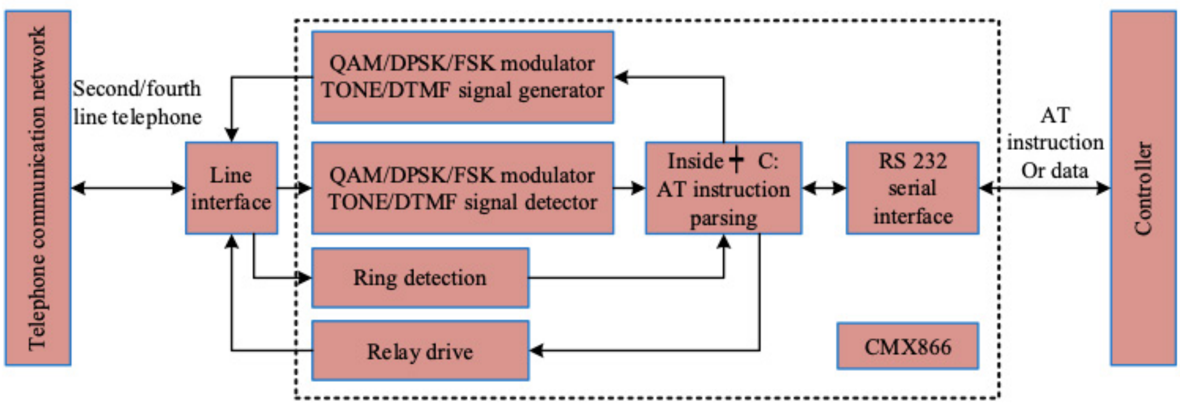

Figure 3. Working principle of demodulator

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2.4. APPLICATION IN GPS SYSTEMS

GPS is a non-self-contained navigation and positioning system developed by the U.S. based on the reception of navigation satellite signals, and this system provides accurate and continuous two-dimensional position and velocity information to global users with appropriate receiving equipment [20]. Widely used in various military and economic fields, along with the promotion and popularization of GPS technology in various fields of application, the miniaturization of the receiver intelligent and meet the user needs of the algorithm research are very necessary [21]. Global positioning system is mainly composed of two parts, the satellite constellation monitoring network and user receiving equipment by the receiving equipment is different. Mainly includes the GPS receiver and its antenna processing transmission 3 output, and a power supply in GPS applications often need to reprocess the data collected by the GPS receiver, or the use of GPS receivers to provide certain information for the development of a certain industry within the DSP, small size, high speed, low power consumption and high reliability characteristics. Suitable for real-time processing of highly complex GPS signals, with its composition with the OEM board GPS information system, not only well meet the GPS signal processing in real time and high complexity, and in the DSP's powerful data processing capabilities of the system can also be further functionality to expand the clock stops, thereby terminating the clock pulse sent to the frequency accumulator. The result is to stop sweeping, so that the output frequency is maintained at the frequency of the hold terminal is valid. After the holdover is released, the clock is restored and the sweep continues. In the hold state, the user can change the value of the register, however, the slope counter must be the original slope to resume work until the count is zero, to load the new slope count initial value.

Phase shift keying means fast switching between two pre-set 14-bit phase shifts, and this switching affects both of the AD9852's 2 converters. The logic state at the BPSK end selects the phase shift, and when it is low, phase 1 is selected, and when it is high, phase 2 is selected. If more phase shifts are required, monotonic mode should be selected, and the phase register should be programmed with either a serial or high-speed parallel bus.

3. DIGITAL SIGNAL PROCESSING ORIENTED ELECTRONIC COMMUNICATION PRACTICES

3.1. SYSTEM DESIGN

The hardware circuit is mainly composed of two parts: the transmitter side and the receiver side. The transmitter side is mainly composed of power supply module, temperature acquisition circuit, microcontroller, wireless transmission module, reset circuit, clock circuit, etc. The transmitter side is mainly to realize that the real-time temperature value is converted into a digital signal to be sent to the microcontroller, and then the serial port of the microcontroller is transported to the wireless signal transceiver module to be sent to the receiver side of the system. The receiving end is shown in Figure 4. To have a power supply module, microcontroller, reset circuit, keyboard circuit, clock circuit, buzzer alarm, wireless receiver module and LCD module and other components. Converted to digital signals, transmitted to the microcontroller, after processing by the microcontroller, the data will be sent to the LCD display module to display the measured value of the sampling end and the buzzer alarm module for over-limit alarm.

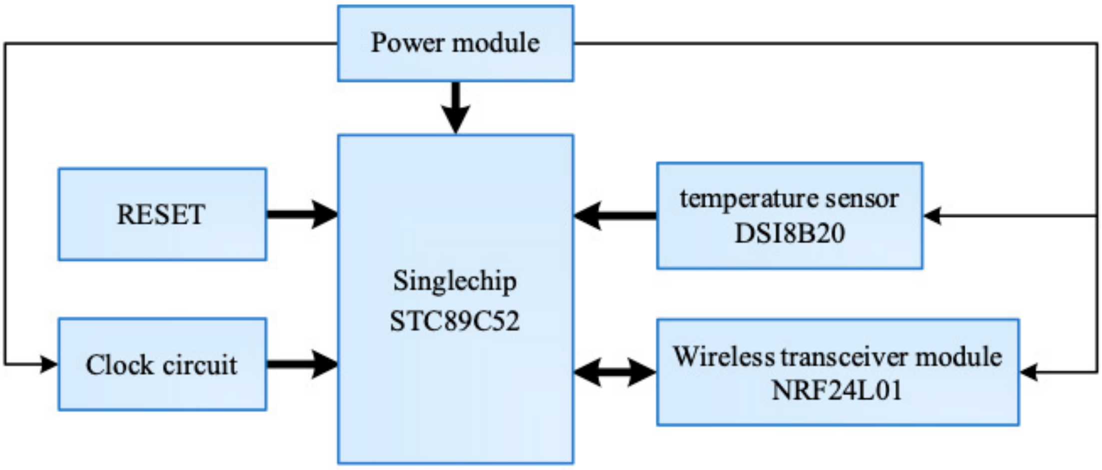

Figure 4. Receiver side

3.2. PLATFORM STRUCTURE

In order to establish the digital signal processing system of electronic information engineering integrated practice platform, Figure 5 shows the DSP processor as the core signal processing unit, integrated man-machine dialogue operation and computer control of the signal processing platform [22-23]. The whole system is mainly composed of two parts: computer and DSP processor. Among them, the DSP processor mainly consists of three parts: memory, interface and real-time channel, which accepts the operation control of the computer and real-time completion of different tasks such as storage, processing and transmission of signal data. Computer to electronic information engineering comprehensive practice, the application of signal processing system, DSP processor to send back the data for further processing. For example, digital analysis, waveform display and so on, at the same time, also control the specific operation of the DSP processor. In this way, through the flexible software loading of digital signals, you can realize the content of different integrated practice of electronic information engineering. The basic principles of modulation and demodulation of the amplitude of the system.

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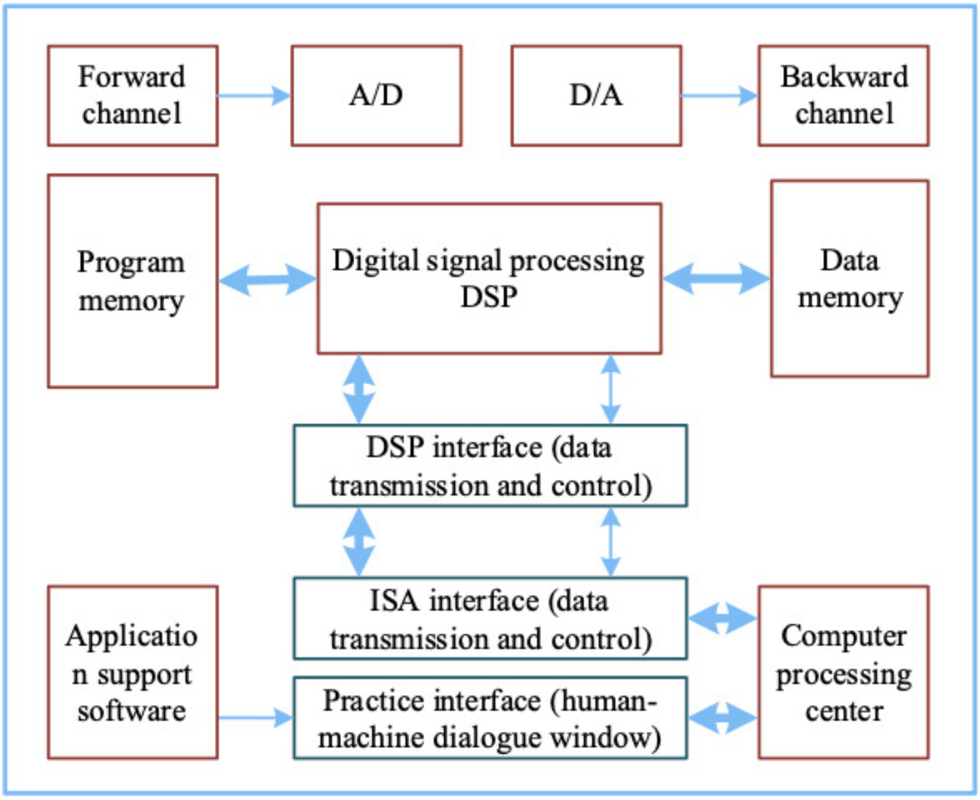


Figure 5. DSP signal processing unit

On the basis of the above system design, the basic principle of modulation and demodulation of the system amplitude is shown in Fig. 6.Amplitude keying uses the amplitude change of the carrier wave to transmit digital information while its frequency and initial phase remain constant. In 2ASK, the amplitude of the carrier wave has only two states of change, corresponding to the binary information 0 or 1.

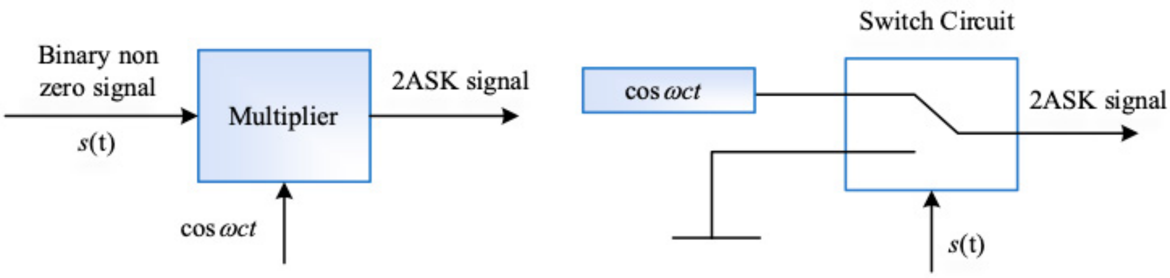


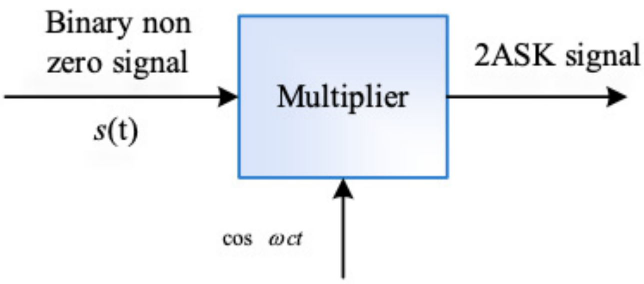
Figure 6. Modulation and demodulation of amplitude control

A common and simplest form of binary amplitude keying is called on-off keying. Its expression is:

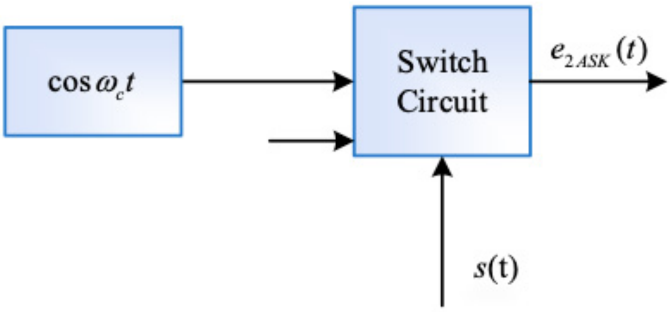
$$e_{ook}(t) = \begin{cases} cA\cos w_c t \\ 0 \end{cases} \quad (2)$$

The general expression for a 2ASK signal is $$e_{2ASK}(t) = s(t)\cos w_c t$$
$$s(t) = \sum_n a_n g\left(t - nT_S\right)\cdot$$

In this case, there are usually two types of binary amplitude keying signals generated, the analog modulation method and the keying method, and the corresponding modulators are shown in Fig. 7. Fig. 7(a) shows the general analog amplitude modulation method, which is implemented with a multiplier. Fig. 7(b) is a digital keying method in which the switching circuit is controlled by s(t). The digital keying method is used in this paper.



(a) General analog amplitude modulation



(b) Digital keying method

Figure 7. Signal modulator principle

As with the demodulation method for AM signals, there are two basic demodulation methods for ASK/OOK signals, the incoherent demodulation envelope detection method and the coherent demodulation synchronization detection method, and the corresponding block diagram of the receiving system composition is shown in Fig. 8. Compared with the receiving system for analog signals, a sampling judge box is added here, which is necessary to improve the receiving performance of digital signals, and coherent demodulation is used in this paper.

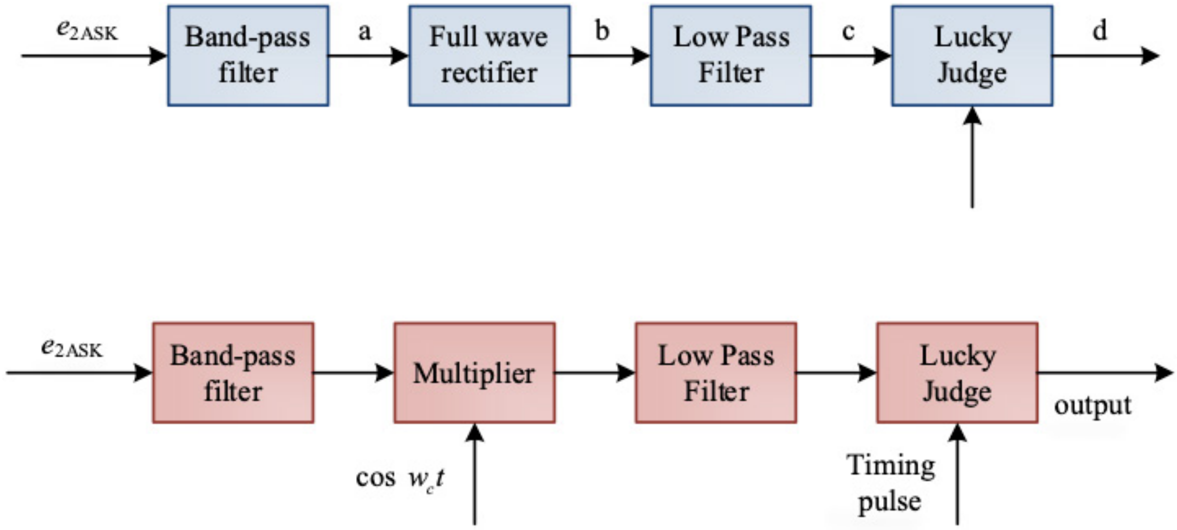


Figure 8. Signal Receiving System Component Box

4. ELECTRONIC COMMUNICATION VERIFICATION FOR DIGITAL SIGNAL PROCESSING

4.1. PERFORMANCE METRICS VALIDATION

In this paper, in the Malthb environment, the communication node information transmission collision avoidance simulation analysis, without considering the control, check redundancy and other data, according to epcglobal company, the proposed coding standard, by the number of communication node labels from 0 to increase to 2200, randomly formed 95-bit information code. Figure 9 shows the results of time complexity analysis, when the number of communication node labels is 0, the time complexity of digital signal processing is 2.5 ms, fiber optic communication is 4.6 ms, and digital technology is 4.9 ms. digital signal processing performs best. As the number of communication node tags increases, the time complexity of all three methods gradually increases. The time complexity of digital signal processing grows relatively slowly, and fiber optic communication and digitization techniques grow faster. The time complexity for the number of communication nodes is 1000 is 7.2 ms for digital signal processing, 14.2 ms for fiber optic communication and 14.89 ms for digitization techniques. Digital signal processing performs the best at this point.

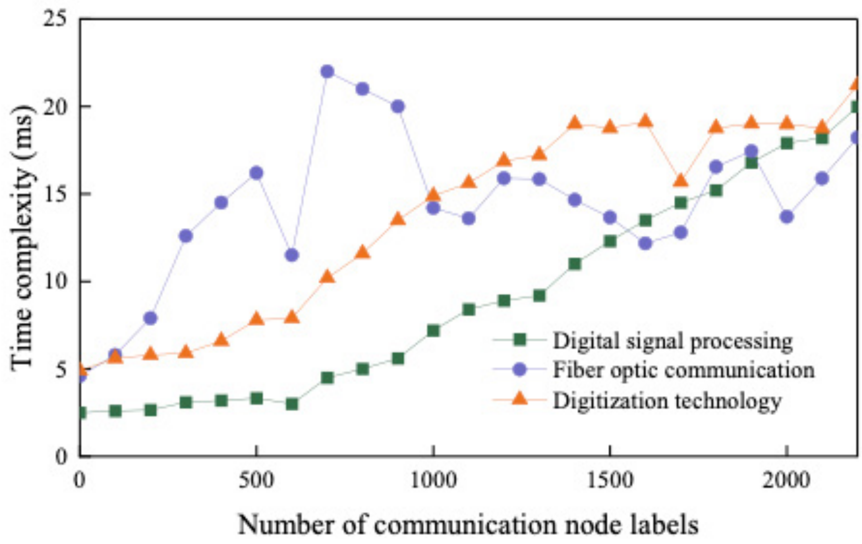


Figure 9. Results of time complexity analysis

The selection of the best communication method for different SNR conditions depends on the specific application requirements and resource budget. Table 1 shows the results of signal-to-noise ratio comparison of different methods, and in all three methods, the performance improves as the signal-to-noise ratio increases. At low signal-to-noise ratios of -10 dB to 0 dB, digital signal processing performs the best and its performance is higher than the other two methods, and digital signal processing can process signals more efficiently under low signal-to-noise ratio conditions. At high signal-to-noise ratios of 35 dB to 40 dB, the performance gap between the three methods becomes smaller, but digital signal processing is still slightly ahead. At low signal-to-noise ratios, the performance gap between digital signal processing and the other two methods is larger, especially at -10 dB signal-to-noise ratio. It indicates that digital signal processing is the best choice for working at low signal-to-noise ratios because it performs best under these conditions.

Table 1. Comparison results of signal-to-noise ratio of different methods

Signal-to-Noise Ratio	Digital signal processing	Fiber optic communications	Digitization technology
-10	2.1	3.9	4.2
-5	2.3	4.1	4.5
0	2.6	4.4	4.8
5	2.9	4.7	5.2
10	3.2	5.0	5.5
15	3.6	5.3	5.9
20	3.9	5.6	6.2
25	4.2	5.9	6.6
30	4.5	6.2	6.9
35	4.8	6.5	7.3
40	5.1	6.8	7.6

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4.2. ALGORITHM EFFICIENCY ANALYSIS

Table 2 shows the efficiency comparison of the three algorithms, where the resource consumption of the digital signal processing method gradually increases from 15% to 38% in the same time. It shows that digital signal processing requires less computational and storage resources to handle the communication task and the resource consumption gradually increases with time. The resource consumption of fiber optic communication methods gradually increases over the same period of time, from 30% to 55%. Although the resource consumption of fiber optic communication is higher than that of digital signal processing, it starts taking more resources at an earlier time. The resource consumption of digitization techniques approach increases from 25% to 46% in the same time period. Although the resource consumption of digitization techniques is between digital signal processing and fibre optic communications, it started to take up more resources at an earlier time.

Table 2. Efficiency of three algorithms

Signal-to-Noise Ratio	Digital signal processing	Fiber optic communications	Digitization technology
-10	2.1	3.9	4.2
-5	2.3	4.1	4.5
0	2.6	4.4	4.8
5	2.9	4.7	5.2
10	3.2	5.0	5.5
15	3.6	5.3	5.9
20	3.9	5.6	6.2
25	4.2	5.9	6.6
30	4.5	6.2	6.9
35	4.8	6.5	7.3
40	5.1	6.8	7.6

4.3. SYSTEM STABILITY AND RELIABILITY TESTING

In terms of system availability, all three methods have very high availability, above 98%. In terms of BER testing, the average BER of all three methods is very low, ranging from 1 × 10-61 × 10-6 to 9 × 10-79 × 10-7 respectively. The pass rates were also high, all above 98%, indicating that these methods performed well in data transmission. The immunity test shows that the digital signal processing techniques have good immunity to interference. The immunity test shows that the digital signal processing has good immunity to interference with a high level of immunity to interference and resistance to multipath interference.

Table 3 System stability and reliability results

Test Items	Indicator	Digital Signal Processing	Fiber Optic Communication	Digitization Technology
System Availability (%)	Mean Time Between Failures (MTBF)	1500h	2000h	1800h
	Mean Time to Repair (MTTR)	30h	40h	35h
	System Availability (MTBF / (MTBF + MTTR))	97.4%	98.0%	98.0%
Bit Error Rate Test	Average Bit Error Rate (BER)	$1\times10^{-6}1\times1^{0-6}$	$8\times10^{-}78\times10^{-7}$	$9\times10-^{7}9\times10^{-7}$
	Maximum Bit Error Rate (BER)	$1\times10-51\times10^{-5}$	$7\times10-67\times10^{-6}$	$8\times10^{-6}8\times10^{-6}$
	Bit Error Rate Test Pass Rate (%)	98.7%	99.2%	99.1%
Anti-jamming Test	Immunity Level (dB)	75 dB	78 dB	76 dB
	Anti-Multipath Interference Performance (dB)	80 dB	82 dB	81 dB
	Phase noise immunity (dBc/Hz)	-110 dBc/Hz	-112 dBc/Hz	-111 dBc/Hz
Data Loss Rate Test	Frequency Shift Resistance (Hz)	1 kHz	800 Hz	900 Hz
	Average Data Loss Rate (%)	0.8%	0.6%	0.7%
	Maximum Data Loss Rate (%)	2.1%	1.8%	2.0%
	Data Loss Pass Rate (%)	96.2%	97.3%	96.9%

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4.4. ENVIRONMENTAL AND DISTURBANCE TESTING

In the application and practice of electronic communication engineering, the testing of environmental and interference factors is crucial and significantly affects the performance and reliability of communication systems. Table 4 shows the results of the interference immunity test, on a high-speed moving vehicle, the signal interference strength is -18 dB, the signal-to-noise ratio is 20 dB, and the BER is 0.015%. This indicates that on mobile vehicles, the communication system can maintain better performance at higher speeds with high signal quality and low BER. In mountainous and forested areas, the signal interference strength is -28 dB, the signal-to-noise ratio is 11 dB, and the BER is 0.05%. This indicates that in complex terrain such as mountainous areas and forests, the communication system may face higher interference with slightly poorer signal quality and slightly higher BER. Over the airplane, the signal interference strength is -12 dB, the signal-to-noise ratio is 22 dB, and the BER is 0.008%. This indicates that at high altitude and in flight, the communication system performs well with high signal quality and very low BER. It is possible to determine the performance of the communication system under different environmental conditions and to be able to take appropriate measures to cope with signal interference and improve the stability and reliability of the system.

Table 4. Anti-interference test results

Test Scene	Signal Interference Strength (dB)	Signal-to-noise ratio (dB)	BER (%)
Indoor environment	-20	15	0.02
Outdoor urban environment	-15	18	0.01
Around tall buildings	-25	12	0.03
On high speed moving vehicles	-18	20	15
Open rural areas	-30	10	0.04
Inside industrial plants	-22	14	25
Mountain woodlands	-28	11	0.05
Coastal areas	-16	19	12
Over airplanes	-12	22	8
Inside subway tunnels	-32	8	0.06

5. CONCLUSION

This paper explores several aspects of digital signal processing oriented electronic communication engineering applications and practices, performance evaluation in different communication scenarios, signal-to-noise ratio comparisons, resource consumption analysis, and system stability and reliability testing. Digital signal processing performs best in most scenarios, with a slower growth in time complexity, and especially excels when the number of communication nodes is 1000. The time complexity of digital signal processing is only 2.5 ms at 0 number of communication node labels, compared to 4.6 ms for fiber optic communication and 4.9 ms for digital technology. Digital signal processing not only excels in performance, but also has a significant advantage in speed and efficiency when dealing with communication tasks. When the signal-to-noise ratio is as low as -10 dB, digital signal processing shows a significant performance advantage over fiber optic communication and digitization techniques. This suggests that digital signal processing is the optimal communications processing method when operating at low signal-to-noise ratios because of the ability to demonstrate superior performance under these harsh conditions.

6. DISCUSSION

With advances in digital signal processing technology, communications systems will be able to provide higher data transmission speeds and greater capacity, enabling rapid transmission and real-time processing of data-intensive applications such as high-definition video, virtual reality, and augmented reality. Digital signal processing will also play a key role in improving the reliability of communication systems by providing more stable communication connections through digital signal processing technologies that can better cope with signal interference, noise and other communication barriers. Future digital signal processors will be more energy efficient while providing higher performance. This is critical for applications such as mobile devices, IoT devices and drones that need to operate for long periods of time. As communication networks expand, security and privacy protection will become critical issues. Digital signal processing can be used to encrypt, decrypt and identify security breaches to ensure secure communications.

ABOUT THE AUTHOR

Qinghe Wang was born in Xuzhou，Jiangsu, P.R. China, in 1980. He received the Master degree from Jiangsu University of Science and Technology, P.R. China. Now, he works in Jiangsu College of Tourism. His research interests include education management, electronic communication engineering, enrollment and employment.

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