Virtual Reality-Based Design and Performance Simulation of Electronic and Communication Systems

Jianghuai Du[1] and Weimin Ma[2]

[1]Computer and Information Technology College, Anhui Vocational and Technical College, Hefei, Anhui 230011, China, azydjh@uta.edu.cn
[2] Intelligent Manufacturing College, Anhui Vocational and Technical College, Hefei, Anhui 230011, China, mwm20011004@163.com

Corresponding author: Jianghuai Du, azydjh@uta.edu.cn

Abstract. Virtual reality technology is the use of computer technology to simulate actual operational scenarios. As a comprehensive technology, virtual reality technology can achieve applications that are difficult to achieve by other technologies but urgently needed by humans, For example, roaming inspection in architectural design, virtual driving, and so on, it has a wide range of applications in various fields. Based on this background, this article proposes the concept and basic composition of virtual communication systems, and studies the key technologies of virtual communication systems using shortwave sky wave channels and ultra shortwave ground wave channels as typical channels. The content mainly includes the basic principles of virtual communication systems, key technologies of virtual simulation systems, and their solutions. The paper ultimately constructed a virtual short wave/ultra short-wave communication experimental system using a star shaped local area network as the platform, with one to multiple transceiver stations. The simulation experiment discussed the implementation of speech communication from the collection and restoration of speech signals, as well as the determination of the capacity and number of speech data buffers. The implementation of the experimental system was discussed and experimented with two modules: virtual channel and virtual radio. The test results showed the feasibility and correctness of the virtual short wave/ultra short-wave communication system.

Keywords: Virtual Reality; Communication System; Simulation
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1 INTRODUCTION

Virtual reality is the use of technological means to create a virtual environment that objectively exists or is abstract, giving people a sense of being present. It integrates technologies in computer graphics, images, three-dimensional vision, stereo sound, artificial intelligence, measurement and control, communication, as well as theories in physiology, psychology, and knowledge science. It is an advanced human-computer interaction technology that highly realistically simulates human behavior such as seeing, listening, and moving in natural environments. Dokhanchi et al. [1] conducted a applicability analysis of steady-state modulated continuous waves. By phase modulation of onboard bistable radar and vehicle to vehicle communication, the statistical boundary of communication signals is derived. Ensure reuse strategy to ensure parameter recognizability. Finally, a low complexity super-resolution algorithm and traditional two-dimensional fast Fourier transform classification were determined through numerical simulation. Ding et al. [2] studied an air ground collaborative communication system, in which the trajectory of the aerial drone base station (UAV BS) and the access control of the ground user (GU) were jointly optimized.

He et al. [3] improved cellular network computing. By integrating D2D communication, it has designed and analyzed the edge nodes of each device. Kanetaki et al. [4] evaluated remote task allocation for online engineering modules through data mining. Revealed the uniqueness of fully online teaching, especially in improving evaluation through digital tools. Traditional multimedia human-machine interface enhancement methods have problems with poor user experience and long runtime. Li [5] proposed a 3D model technology based on virtual reality to generate objects. It enhances the virtual environment through a multimedia human-machine interface. Advanced communication and networking have greatly enhanced the user experience. In complex network propagation environments, drones effectively obtain link reflections from the intelligent surface of the network. Li et al. [6] reconstructed surface signals and designed trajectory beamforming for unmanned aerial vehicle communication systems. Through the relative calibration of the received signals in different transmission paths, the optimal phase shift solution is obtained by using the successive convex approximation method. The results show that the proposed algorithm can significantly improve its implementation rate in passive beamforming and trajectory optimization. Lu et al. [7] achieved data transmission and exchange in fields such as computer-aided design and computer-aided manufacturing (CAD/CAM). By integrating and analyzing user virtual network resources, data exchange between different devices was carried out.

In this context, this article studies a virtual communication system based on virtual radio technology, with a computer as the platform and software as the core to complete the communication functions of multiple radio devices. Firstly, based on the spectral shift principle of linear modulation, the virtual communication system is equivalent to a baseband system. Secondly, based on the basic principles of virtual reality, the key technologies and solutions of virtual short wave/ultra short-wave communication systems were discussed. Finally, a virtual shortwave/ultra shortwave communication experimental system was presented, and its structure, composition, and working principles of the virtual radio and virtual channel modules were discussed. The main performance was tested, and the results verified the correctness and feasibility of the key technologies implemented in the virtual communication system.

2 STATE OF THE ART

According to the concept of virtual reality, a virtual communication system should be composed of virtual radio stations and virtual channels. Ma et al. [8] systematically investigated the latest developments in IoT infrastructure from several perspectives. Energy collection provides a feasible alternative to autonomous power supply for IoT devices. It overcomes the main limitations of the sustainability of infrastructure such as battery maintenance. Different from virtual systems such as virtual driving that generate three-dimensional image effects, the technical approaches adopted by the two are also different. The relationship between the functional modules is shown in Figure 1.

Virtual communication system is a virtual communication system based on computers, which can be implemented using virtual radio technology. Virtual radio technology is a new development trend in software radio technology. Software radio is an emerging technology in communication systems.

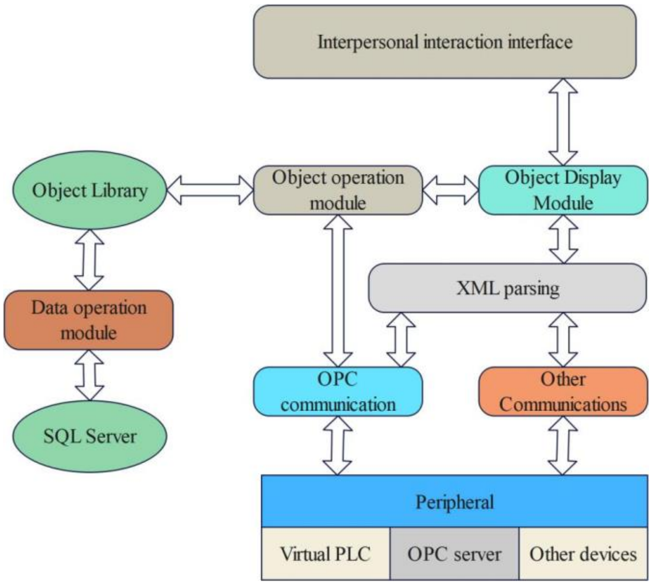

Figure 1: Virtual electronic communication system software system block diagram.

Computer assisted simulation of power and communication systems refers to the process of simulating and analyzing power and communication systems using computer technology and simulation techniques. Mana et al. [9] used computer software to establish a mathematical model of the power system, simulating various physical processes of the system, including power flow, load distribution, voltage control, etc. Sun et al. [10] used simulation software to conduct simulation analysis on power systems, studying system performance, stability, optimization methods, etc. Based on simulation results, optimize control of the power system, including adjusting operation mode, improving equipment design, optimizing power grid structure, etc. Establish a mathematical model of the communication system using computer software to simulate the transmission and processing of communication signals, including signal modulation, channel coding, channel noise, etc. As shown in Figure 2, the difference between virtual radio and traditional software radio is that it is not a specialized digital hardware application controlled by software or implemented by DSP chips, but rather starts from the computer architecture, which fully utilizes the computer's cache space and programming capabilities to achieve software radio. Virtual reality (VR) has developed as a collaborative, realistic, and creative computing technology. As organizations pay more and more attention to digitalization, the experience of employees is also changing due to technology. Managers face and continue to face some obstacles in the process of Digital transformation. With the widespread application of deep learning and the Internet of Things, the training of semantic communication design models based on cloud edge platforms has become increasingly important. Xie and Qin [11] have improved the propagation impact of the training process through data edge transmission on IoT devices. Reduce the impact of fading channels on transmission by developing a signal state information. At the same time, we have adjusted the semantic constellation to enable it to be implemented on IoT devices with limited capacity. Simulation shows that compared to traditional methods, the proposed L-DeepSC achieves competitive performance, especially in low signal-to-noise ratio (SNR) regions. Zhang et al. [12] proposed a visual improved digital media communication framework using VR technology and DT. This framework can help optimize repetitive processes and make complex decisions in real-time by replicating physical systems and adding virtual reality and digital mirrors in virtual design.

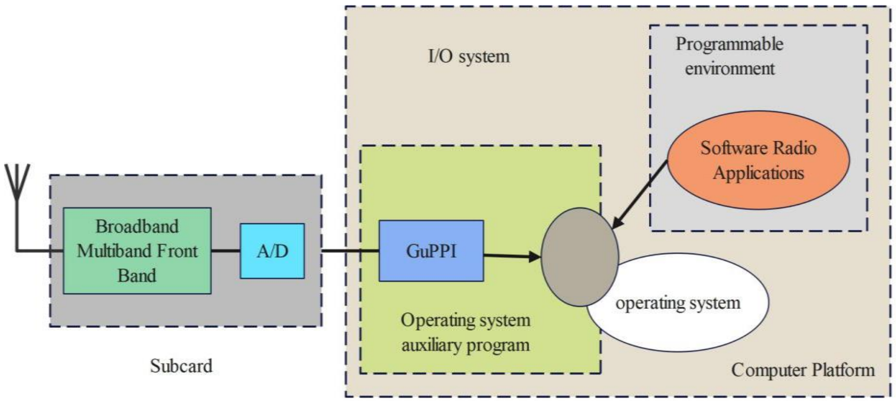

Figure 2: Virtual electronic communication system software system block diagram.

UAV assisted mobile edge computing is a new computing paradigm, which aims to improve the computing and storage capacity of terminals, and transfer computing to the cloud through mobile networks, thus reducing the energy consumption of terminals. In this computing paradigm, drones are used as computing resources and can provide offloading services for nearby user devices. The computing power of drones can assist terminals in completing computationally intensive tasks, thereby reducing terminal energy consumption and latency. Zhang et al. [13] believe that in mobile edge computing, UAVs can be used to offload some computing tasks to the local terminal, thus reducing the energy consumption and delay of the terminal. Zhou et al. [14] reduced the energy consumption of terminals by transferring computing from mobile networks to the cloud. In this computing paradigm, drones are used as computing resources and can provide offloading services for nearby user devices. The numerical results show that the proposed algorithm is significantly superior to the baseline strategy in terms of large-scale unmanned aerial vehicle self-interference (SI) efficiency, location, and data packet size for ground users. The virtual communication system not only needs to input voice, data, message and other signals at the transmitting station, but also needs to output voice, data, message and other signals through the channel at the receiving station. Therefore, based on the computer platform of the virtual radio structure, the virtual communication system is implemented by changing the interface with the IO system. Zhang et al. [15] conducted task signal matching task analysis for drone mobile computing. By offloading the task bits from the AV relay to the access point within a limited amount of time. It proposes a new optimization problem formula. The aim is to minimize total energy consumption by optimizing bit allocation, slot scheduling, power allocation, and drone trajectory design. By calculation and analysis. It verifies the technical effectiveness of the algorithm.

3 METHODOLOGY

3.1 Basic Principles of Virtual Communication Systems

In communication systems, signals output from the source, such as voice signals, image signals, etc., are low-pass signals, and their spectral characteristics include (or do not include) the low-pass spectrum of the DC component. The ratio of the highest frequency to the lowest frequency is much greater than 1, and a large amount of energy is distributed at the low end of the spectrum, so they are called baseband signals. In order to enable baseband signals to be transmitted in frequency bands like wireless channels, and also to simultaneously transmit multiple baseband signals on wired channels, modulation and demodulation techniques are needed.

The most commonly used modulation method in shortwave/ultra shortwave communication is amplitude modulation single sideband, which belongs to linear modulation technology. Linear modulation technology is a modulation technique that exhibits a linear shift relationship between the frequency spectrum of the output modulated signal and the frequency spectrum of the modulated signal. Specifically, from a frequency domain perspective, its spectrum is completely a linear shift of the baseband signal spectrum structure within the frequency domain.

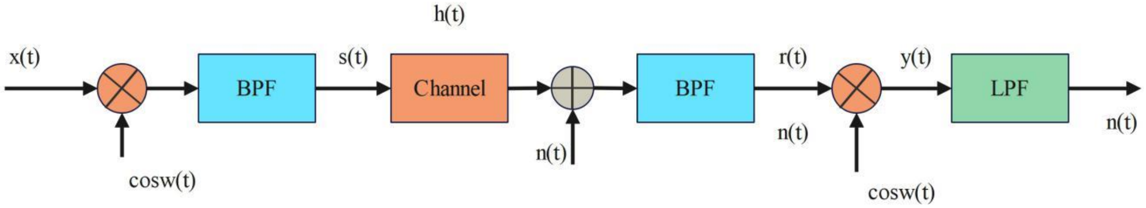

Figure 3: Schematic diagram of linear modulation system.

The schematic diagram of the linear modulation system is shown in Figure 3. From the figure, it can be seen that the baseband input signal is x (t), First, it undergoes modulation (including filtering). Obtain the modulated signal s (t), transmit it through the channel, and then pass through a bandpass filter at the receiving end to filter out noise interference outside the signal band; By synchronous demodulation, a copy of the input signal is obtained.

Set the baseband input signal x (t) to be linearly modulated as a modulated signal

$$s(t) = x(t)\cos\omega_c t \tag{1}$$

Represented in frequency domain as

$$s(\omega) = \frac{1}{2}\left[X(\omega-\omega_c) + X(\omega+\omega_c)\right] \tag{2}$$

Regardless of noise, the received signal r (t) is represented in the time domain as

$$r(t) = s(t) * h(t) \tag{3}$$

Represented in frequency domain as

$$R(\omega) = S(\omega) \bullet H(\omega) \tag{4}$$

Among R (·) is the Fourier transform of the signal r (t) before demodulation; S (·) is the Fourier transform of the self-modulated signal s (t). Thus, there are

$$R(\omega) = \frac{1}{2}\left[X(\omega-\omega_c) + X(\omega+\omega_c)\right]H(\omega) \tag{5}$$

Coherent demodulation of r (t) is performed by first passing through a multiplier to obtain the signal y (t):

$$y(t) = r(t)\cos\omega_c t \tag{6}$$

Represented in frequency domain as

$$Y(\omega) = \frac{1}{2}\left[R(\omega-\omega_c) + R(\omega+\omega_c)\right] \tag{7}$$

Substituting equation (5) into equation (7) yields

$$\begin{aligned} Y(\omega) = \frac{1}{4}[&X(\omega-2\omega_c)H(\omega-\omega_c) + X(\omega)H(\omega-\omega_c) + \\ &X(\omega)H(\omega+\omega_c) + X(\omega+2\omega_c)H(\omega+\omega_c)] \end{aligned} \tag{8}$$

The demodulated signal obtained by low-pass filtering of y (t) in the frequency domain includes

$$X(\omega)=\frac{1}{4}X(\omega)[H(\omega-\omega_c)+H(\omega+\omega_c)] \tag{9}$$

For linear modulation systems, it is allowed to ignore any linear frequency shift encountered in signal modulation. Therefore, under ideal modulation and coherent demodulation conditions, narrowband communication systems can be equivalent using an equivalent baseband model, that is, the input baseband signal can be directly used to obtain the output baseband signal through the equivalent baseband channel without undergoing modulation and demodulation processes.

The actual channel transmission is a carrier frequency narrowband signal with bandpass characteristics. Therefore, in the equivalent baseband model of communication systems, the baseband equivalence of the bandpass characteristics of the channel is crucial. Assuming that the input signal of the skywave channel is the carrier of shortwave communication

$$x(t)=\cos(2\pi f_c t) \tag{10}$$

And its Fourier transform is

$$X(f)=\frac{1}{2}[\delta(f+f_c)+\delta(f-f_c)] \tag{11}$$

Due to the multipath effect of the ionosphere in the sky wave channel, the propagation delay and attenuation factor both randomly change due to changes in the ionospheric medium structure. Therefore, the received signal after multipath propagation will be the synthesis of signals from each path whose attenuation and delay change with time. So the received signal can be represented by the following equation:

$$x(t)=\sum_1^n a(t)\cos[\omega_c(t+\tau(t))] \tag{12}$$

In terms of waveform, in the process of ionospheric short-wave propagation, the result of multipath propagation makes the single frequency sine signal become a narrowband signal with envelope and phase modulated, making the received signal level show irregular changes, as shown in Figure 4. The phenomenon of random fluctuations in amplitude is called fading, and such signals are usually referred to as fading signals. From the perspective of spectrum, multipath propagation and ionospheric inhomogeneity will cause random fluctuations in signal phase, leading to frequency dispersion, that is, a single frequency spectrum line becomes a narrowband spectrum. The phenomenon of random fluctuations in the phase of such signals is called Doppler spread spectrum.

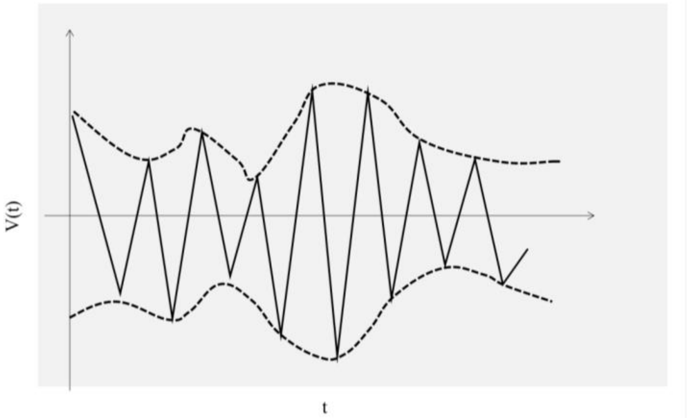

Figure 4: Waveform of fading signal.

3.2 Key Technologies and Solutions of Communication Systems

Make the operator feel 'realistic' It is necessary to ensure the realism of the operation and functionality of virtual channels and virtual radio stations. The fidelity of virtual channels depends on the virtual channel model, which depends on the parameters of the virtual channel model, which vary with the propagation environment. Therefore, determining the parameters of the virtual channel model based on the propagation environment is one of the key technologies for implementing virtual shortwave/ultra shortwave communication systems. A virtual channel established based on the physical process and characteristics of radio wave propagation in the channel can be described using mathematical models, which can realistically achieve the true impact of the channel on communication performance.

In shortwave skywave transmission, this system only considers the single hop situation, so the transmission loss mainly comes from two aspects: free space propagation loss and ionospheric absorption loss. In addition to these two types of losses, other losses (such as polarization loss, ionospheric offset absorption loss, etc.) are commonly referred to as additional system losses. So the skywave propagation loss L can be expressed as:

$$[L_p]=[L_{p0}]+[L_a]+[Y_p] \tag{13}$$

Among them are free space propagation loss, ionospheric absorption loss, and additional system loss. The free propagation loss is expressed as:

$$[L_{p0}]=32.44+20\lg f+20\lg r \qquad (dB) \tag{14}$$

The sources of additive noise in ultra short-wave ground wave channels can generally be divided into internal noise, natural noise, and artificial noise. Internal noise refers to various types of noise generated by the system equipment itself. External noise mainly includes Atmospheric noise, solar noise and Galaxy noise. The frequency range of ultrashort wave radio station is generally 30MHz~88MHz. Above 30MHz, Atmospheric noise and solar noise (inactive period) are very small and can be ignored; The galactic noise is lower than the internal noise of the receiver and can also be ignored. Due to the consideration of plain and hilly terrain, human noise can also be ignored.

During ground wave transmission, diffraction occurs when the wireless path between the transmitter and receiver is obstructed by sharp edges. The secondary waves generated by the blocking surface are scattered in space, even on the back of the blocking body. Diffraction causes radio signals to propagate around the curved surface of the Earth, enabling them to propagate behind obstacles. Although the receiving field strength decays very quickly when the receiver moves to the shaded area of the obstruction, the diffraction field still exists and often has sufficient strength. Due to the complexity of calculating the received power under diffraction conditions, in general, compared to the free space propagation method, the diffraction gain caused by the blade shape is directly calculated as:

$$Gd(dB)=20\lg|F(v)| \tag{15}$$

3.3 Construction of Communication System Platform

According to the principles of virtual communication systems. The virtual communication system consists of a control center and multiple virtual radio stations. Building a virtual communication system platform based on the framework of virtual radio, but the difference with virtual radio is that its input and output signals are voice signals, which are operated by virtual radio and enter the control center. Therefore, the virtual communication system platform is composed of a control center and a virtual radio. To achieve frequent data transmission between virtual radio stations and control centers, the virtual short wave/ultra short-wave communication system platform should also include a star LAN system for data transmission between the control center and multiple virtual radio stations.

The virtual short wave/ultra short-wave communication system is a virtual communication local area network system constructed based on a radio framework, mainly composed of a control center, virtual radio, and a switch. The control center and virtual radio are both implemented by computers. The control center is equivalent to a programmable environment in virtual radio, and the virtual radio is equivalent to the RF signal input by the virtual radio. The switch is used to achieve data transmission between the control center and the virtual radio, which is equivalent to the I/O system in the virtual radio structure. In addition, both the virtual radio and the control center are connected to the switch through a dedicated non shielded twisted pair cable, and both must be configured with network adapters.

In summary, in a virtual communication local area network system, the server implements the function of the control center and is served by a high-speed and high-capacity computer; The client realizes the function of a virtual radio station, which can be implemented using a regular computer; The client, virtual radio station, and server, control center form a virtual training system platform with a switch as the contact point.

Considering that in a multi radio virtual communication system, the control center must perform virtual channel processing for communication voice for each pair of transmitting and receiving stations. When there are many transmitting and receiving stations, the data processing workload of the virtual channel in the control center is quite large, the server's burden is too heavy, and the data processing speed decreases, making it difficult for a computer to bear, and the real-time performance of the system will also decrease; And each virtual radio station is only responsible for the implementation of communication virtual effects, that is, the collection and restoration of voice data. Apart from a small amount of voice data generation and transmission data, the workload is relatively small. Therefore, in order to further optimize network resources, improve data processing speed, and improve the "real-time" of the system, the data processing of the virtual channel model adopts distributed computing, that is, the virtual channel processing work is moved from the control center to each virtual receiving station, and the control center is only responsible for transmitting various parameter data required for the data processing of the virtual channel model, The implementation of virtual channel processing by various virtual radio stations based on the parameter data provided by the control center. This only adds a small amount of data transmission to the network, but the data processing work of the control center is greatly reduced, which is conducive to the reliable transmission of the system and can expand the radio capacity of the system.

4 RESULT ANALYSIS AND DISCUSSION

4.1 Construction of Virtual Short Wave/Ultra Short-Wave Communication Experimental System

The virtual short wave/ultra short-wave communication system is a virtual communication system that uses a star shaped local area network as the platform for communication between multiple virtual radio stations. This article constructs a virtual short wave/ultra short-wave communication experimental system for a pair of transceiver stations to verify the key technologies of the virtual short wave/ultra short-wave communication system. The working process of the entire virtual communication system is as follows:

(1) After the system is started, the user management program in the control center assigns communication tasks to the virtual radio station, which includes setting various parameters such as the geographical environment and communication types between the virtual radio stations, as well as the interference of the jammer. These parameters are transmitted to each virtual radio station through the network management function of the server in the control center.

(2) After receiving training tasks from the control center, each virtual radio station begins to set the operating parameters of the radio station, Then it is transmitted to the user management section of the control center through the network.

(3) The user management section of the control center calls the data management function to determine whether the operating parameters of the virtual radio station are set correctly and

whether communication can be carried out based on the operating parameters transmitted by each virtual radio station, including radio station model, operating frequency, etc. If correct, the control center will transmit the current channel model parameters of the virtual radio to the virtual radio, and the virtual radio will begin communication.

(4) Considering that the voice signals transmitted between radio stations may add analog interference signals, the voice signals sent by virtual radio stations must be transmitted to the control center and superimposed with analog interference signals. So, the control center processes and transmits voice data based on the virtual radio station, including the voice transmitted by the same frequency interference radio station. The virtual radio station receives parameters and voice data from the control center, processes the voice data through the virtual channel, and restores it to speech, thus completing the virtual communication function.

(5) The control center can pause, continue, and terminate communication training at any time.

4.2 Experimental Results and Analysis

In order to verify the correctness of the implementation of the Watterson model, this article conducted experiments on the settings of delay, Doppler shift, Doppler spread, and signal-to-noise ratio for this model. In order to make the experimental results more intuitive, a 1KHz single frequency sine signal was used as the input signal, and the channel models were set to single path without path delay and 0.5ms path delay, respectively, without Doppler frequency shift, Doppler spread, and additive noise. The time-domain waveform of the channel model output signal in both cases is shown in Figure 5. The solid and dashed lines in the figure represent waveforms with zero delay and 0.5ms delay, respectively. From this figure, it can be seen that the channel model achieved a path delay of 0.5ms.

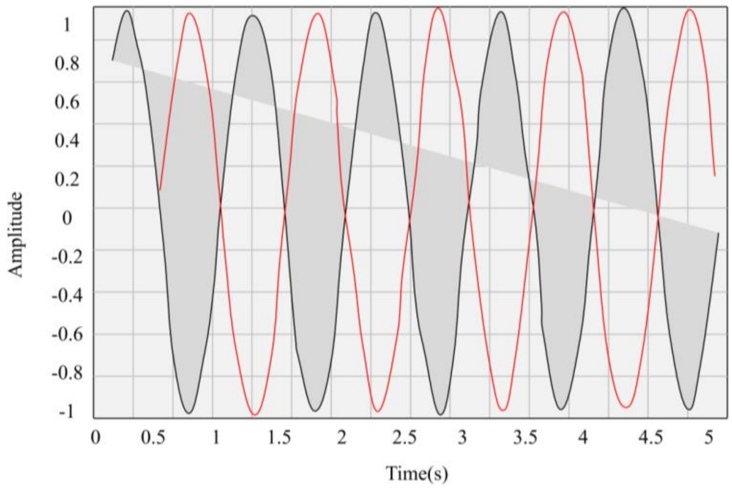

Figure 5: Sine wave with zero delay and 0.5ms path delay.

The allocation strategy for the optimal number of subchannels in the system is shown in Figure 6, where we compare the simulation results of two resource optimization strategies. Figure 7 shows the spectral efficiency comparison curves of different schemes. The input signal is a sine wave of 1KHz, and the shortwave skywave channel model is set to dual paths with no Doppler spread or path delay, One of the paths has no Doppler frequency shift, while the other path has a Doppler frequency shift. Then, testing was conducted and the output data was subjected to spectral analysis. Figure 8 shows the amplitude spectrum of the output signal of the channel simulator.

From the figure, it can be seen that the spacing between the two spectral lines is about 100Hz, indicating that the implementation of Doppler frequency shift in the channel model meets the requirements.

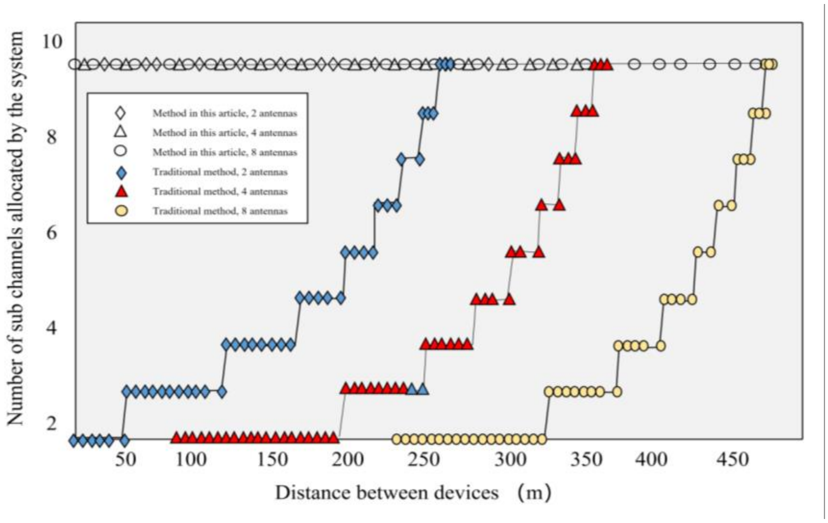

Figure 6: The optimal number of subchannels allocated to each device during virtual simulation.

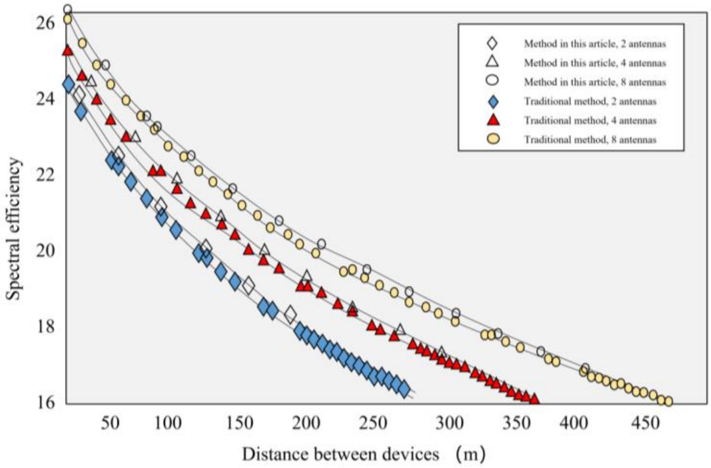

Figure 7: Spectral efficiency of communication system.

This section introduces the structure and specific implementation methods of the virtual shortwave/ultra shortwave communication experimental system, and conducts experiments on its main modules. The experimental results demonstrate the "fidelity" of the virtual short wave/ultra short-wave communication experimental system for virtual radio communication with a single radio station. Due to the fact that the virtual short wave/ultra short-wave communication experimental system is implemented based on the key technologies and architecture of the virtual short wave/ultra short-wave communication system, it also indicates the correctness of the key technologies and architecture of the virtual short wave/ultra short-wave communication system.

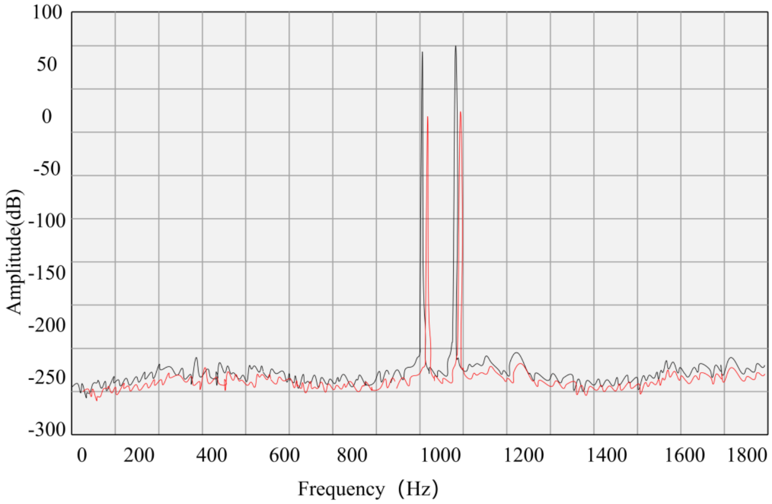

Figure 8: Spectral efficiency of communication system.

5 CONCLUSION

With the rapid development of the new military revolution worldwide, various high-tech technologies have been widely used in the military field, and weapons and equipment are increasingly developing towards electronics, informatization, and intelligence. The right to control information has become a commanding point in the battle for battlefield initiative. The virtual training revolution based on virtual reality technology has swept the world and received widespread attention and application from military forces in various countries, becoming an important way of military training today. Modern war is an information war of high-tech competition, and communication system is the central nerve of war command. However, for a long time, there has been a significant gap between the anti-interference training level of communication forces and the requirements of actual combat. Communication troops trained in a non-interference environment are difficult to successfully complete communication tasks in interference environments. Therefore, it is imperative to use virtual reality technology to construct a virtual communication training system in interference environments. The virtual communication system in this article is a virtual communication system based on virtual radio technology, with a computer as the platform and software as the core, which completes the communication functions of multiple radio devices, including virtual channel functions and virtual radio device functions. In order to verify the correctness and feasibility of the key technologies and solutions of the virtual short wave/ultra short-wave communication system, a virtual short wave/ultra short-wave communication experimental system for a pair of transmitting and receiving radio stations was constructed on a computer platform using a star LAN network. The test results indicate the feasibility and correctness of the virtual shortwave/ultra shortwave communication system.

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Jianghuai Du, https://orcid.org/0000-0001-6663-1241
Weimin Ma, https://orcid.org/0009-0009-6255-1274

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